ELEMENTARY

BOTANY

EDMONDS.

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ELEMENTARY BOTANY

THEORETICAL AND PRACTICAL

BY

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HONOURS IN BOTANY, SOUTH KENSINGTON
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OF SCIENCE AND ART

NEW EDITION

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PREFACE

TO

THE NEW EDITION

THE previous editions of this little work having been so well received, and the book itself being so widely used throughout the kingdom, the present opportunity has been taken of bringing it up to date. The whole has been thoroughly revised and in many parts rewritten; chapters on Practical Work have been added, and the Appendix has been enlarged so as to completely cover the syllabus of the Oxford and Cambridge Local Examinations.

Students are strongly urged not to content themselves with reading the theoretical parts of the book and referring to the diagrams, but to perform for themselves the various dissections and experiments contained in the practical chapters. It is only thus, and by a continuous and careful examination of the living plants in the garden, by the wayside and in the field, and in the hothouse, that an intelligent understanding of Botany can be obtained.

H. EDMONDS.

BRIGHTON,
September, 1899.

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ELEMENTARY BOTANY

CHAPTER I.

INTRODUCTORY—DEFINITION AND SCOPE OF THE SCIENCE.

BOTANY is the science which deals with those special forms of living organisms known as Plants. This at once raises the question—What do we mean by a plant? The higher forms of animal and vegetable life can be easily distinguished the one from the other; but when we descend to the lower forms we find it most difficult, if not impossible, to draw a line of demarcation between them.

The old distinction between the three kingdoms of nature was a simple one: minerals grow—plants live and grow—animals move, live, and grow. Putting aside for the moment the question as to whether minerals really grow, the phenomena of motion cannot be accepted as defining the difference between the two groups of living beings. Many plants, especially amongst the lower forms, are capable of motion at some time or other during their life. As an example, if we examine rain-water that has been standing for some days, we often find minute green masses floating about in it. These on inspection under a microscope prove to be true plants (*Chlamydomonas pulvisculus*), each being a little round or oval structure consisting of a jelly-like substance, the protoplasm, contained within a delicate cell wall. Embedded in the protoplasm is a green body, the chlorophyll granule. Some of these individuals may be seen to lie motionless in the water, but others will be found to be moving with considerable velocity. This movement is effected by the prolongation of two whip-like processes of the protoplasm—the cilia—through the anterior narrower

end of the cell. A red "eye-spot" may often be distinguished in this region. In its motile condition *Chlamydomonas* resembles many of the lower forms of animal life, but the latter do not possess chlorophyll nor a cell wall.

A better distinction between plants and animals is to be found in the **food** that is assimilated. **Plants,** like animals, require food; but they, as a rule, possess the power of **obtaining it from the mineral kingdom only,** whilst **animals require** for their food **either vegetable or animal substances.** There are, however, exceptions to this rule, and, as we have said, the two kingdoms appear to merge gradually the one into the other in their lower forms.

Botany, then, being the science which treats of plants, has several branches. *Morphology* deals with the forms of the organs of plants. *Anatomy* treats of their internal structure: and *Histology* of the minute appearance they present under the microscope. *Physiology* deals with the functions of the various organs, and the phenomena attendant upon life. *Classification* has to do with the grouping of plants according to their relation one to another. *Geographical Botany* deals with the distribution of plants in space; and *Palæontological Botany* with their distribution in time. Of these we shall omit the two latter branches in the present work, merely taking up in an elementary form the remaining departments.

CHAPTER II.

FLOWERING AND FLOWERLESS PLANTS—STRUCTURE OF THE SEED.

All the **higher forms of plant life** are distinguished as being able, at some time or other of their existence, to **produce flowers.**

It is this fact which causes the Vegetable Kingdom to be divided into the two sub-kingdoms of **Flowering Plants** or **Phanerogams,** and **Flowerless Plants** or **Cryptogams.**

In the present work we shall deal chiefly with the Phanerogams.

The point in which **all of these plants** agree is that they **spring originally from seeds.** To understand a seed thoroughly, it is well to commence with a large specimen, as, for instance, a Broad Bean, Haricot, or a Pea.

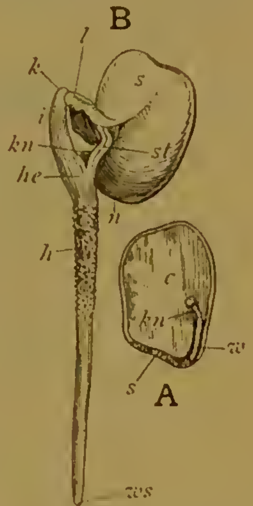

Fig. 1.—Broad Bean. *A*, seed, with one cotyledon removed; *c*, remaining cotyledon; *kn*, the plumule; *w*, the radicle; *s*, the spermoderm. *B*, germinating seed: *s*, spermoderm, a portion torn away at *l*; *n*, hilum; *st*, petiole of one of the cotyledons; *k*, curved epicotyledonary portion of axis, *i*; *he*, short hypocotyledonary portion of axis; *h*, main root; *ws*, its apex, *kn*, bud in axil of one of the cotyledons. (After Sachs.)

If we examine a Broad Bean carefully, we notice that it has an elongated shape. At one end there is a scar, or mark. This is the point by which the seed is attached to the fruit, and is known as the **hilum.** At one end of this there is a minute hole. This can be readily seen by allowing the bean to soak in hot water for a short time; then on taking it out and squeezing it a drop of water is seen to escape through the aperture. This hole, which leads into the interior of the seed, is called the **micropyle.**

Next, taking a sharp penknife, we find that we can peel the skin from off the seed, leaving a whitish fleshy mass within.

This **skin** is sometimes called the **testa**,[1] and it is often observed to be double.

Within the testa the large **embryo** will be found to make up the main bulk of the seed. This is the part that will grow into the future plant, and it consists of—(1) two large fleshy lobes, the seed-leaves, or **cotyledons**; and (2) of a small curved structure lying between them, termed the **plumule**, which will form the stem and, later, leaves of the young plantlet: and (3) of a straight pointed body, the **radicle**, the end of which forms the main tap-root, and is always directed, in all seeds, towards the micropyle.

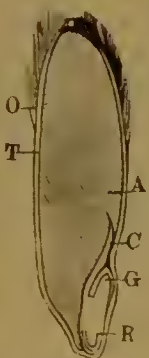

Fig. 2.—Longitudinal section of a fruit of Oat: A, endosperm; C, the single cotyledon; G, plumule; R, radicle; T, fruit wall; O, hairs.

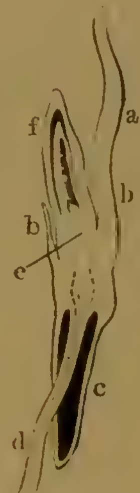

Fig. 3.—Germination of the Oat: *a*, cotyledon; *c*, axis of the embryo; *d*, radicle; *f*, plumule.

In some seeds, as in the castor-oil bean, or in a grain of oat, there is in the seed a further substance in addition to the embryo (Fig. 2). This is termed **albumen**. This albumen may originate from two different parts of the ovule, and hence is known either as **endosperm** or **perisperm**.

This will be more apparent when we have dealt with the growth of the ovule.

The term "albumen" is rather a misleading one, as it might lead the student to imagine that the substance contained within

[1] The seed-coat is sometimes termed the **spermoderm**, the outer layer being distinguished as the **testa**, the inner as the **tegmen**.

the seed is identical in chemical composition with animal albumen, such as is found in the white of an egg, whereas it differs in its characteristics in various plants. In cereals it is *mealy* or *farinaceous*; in the Barberry and Heart's-ease it is *fleshy*; in the Poppy and Cocoanut it is *oily*; in the Mallow, *mucilaginous*: in the Vegetable Ivory and Coffee, *horny*.

Seeds containing albumen are spoken of as **albuminous**, whilst those **destitute of it** are **exalbuminous**.

There is another point in which seeds differ. On examining a grain of Wheat,[1] or of an allied cereal, we find that there is only one cotyledon present, instead of, as in the case of the Bean, two. Many plants resemble the Bean in having two cotyledons present in their embryos; whilst others, like Oats, have but one. This character serves as a means of subdividing the great section of flowering plants, known as **Angiosperms**, into two groups; **Dicotyledons** include those angiosperms that possess two cotyledons, whilst **Monocotyledons** comprise those that only possess one cotyledon.

[1] The grain of wheat is a fruit. not merely a seed.

CHAPTER III.

CELL STRUCTURE.

THE substance of the Bean seed is not homogeneous. The **whole of the various organs** of plants are **made up of** a large number of component parts—**cells,** so minute as a rule as to be invisible separately to the naked eye. If a little brewer's Yeast be examined under a hand magnifying glass, it is seen to present a granular appearance. If it be more highly magnified, it is found to consist of a large number of minute rounded particles (Fig. 4); these are separate cells. We recognise in them the outer pellicle, or cell wall, and the cell contents.

FIG. 4.—Beer Yeast (*Saccharomyces* [*Torula*] *Cerevisiæ*).

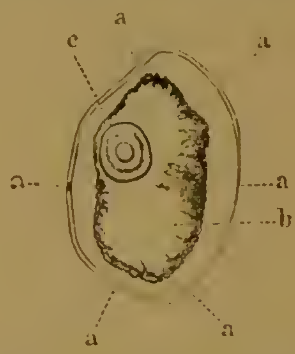

FIG. 5.—A cell from the root of the Lizard Orchis (*Orchis hircina*); *a*, the cell wall, consisting of cellulose; *b*, the protoplasm, contracted by alcohol; *c*, the nucleus with a nucleolus.

The **cell wall** may be absent during a portion of the cell's existence; it is simply inert, not-living matter: but in the Vegetable Kingdom it is always sooner or later produced. The principal substance contained in it is **cellulose,** a compound of carbon, hydrogen, and oxygen, having the chemical composition $(C_6H_{10}O_5)_n$, the hydrogen and oxygen being in the right proportions to form water.

Such a compound, consisting of carbon and the elements of

water, is called a **carbohydrate.** Other examples of carbohydrates are starch, sugar, and gum.

Cellulose is not coloured blue by means of iodine alone, although it is so changed by the action of iodine and sulphuric acid, thus being distinguishable from starch, which has the same percentage composition, but is turned blue by iodine. Schultze's solution [1] will also stain cellulose.

Cellulose is insoluble in water, both cold and boiling; also in alcohol, ether, and dilute acids. If it be treated with cold concentrated sulphuric acid, it is converted first into dextrine, or British gum, which is the same composition as cellulose, and then into grape sugar, $C_6H_{12}O_6$. It is found almost pure in Cotton wool, but generally the cell wall contains mineral ash and water in addition.

During the growth of the cell the cellulose is often converted into substances which are of an allied composition, but which differ from it in various physical and chemical properties.

The chief of these are—

1. **Suber, or Cuticularised Cellulose.**—This is highly elastic and almost impermeable to water; when treated with iodine or Schultze's solution it turns yellow; when warmed (not boiled) in concentrated solution of potash it is stained bright yellow. It is met with in cork, epidermis cells, and pollen grains.

2. **Lignin.**—In this case the cell wall is hard, inelastic, and permeable to water. Treated with a solution of aniline sulphate acidulated with a few drops of sulphuric acid, it is stained yellow. It is met with in wood cells.

3. **Mucilage.**—When dry it is hard and horny, but it very readily absorbs water, swelling and becoming gelatinous. The reactions are for the most part the same as those of cellulose. Examples are to be found in Linseed and Quince mucilage.

The **cell contents** are very various; we will note some of the principal:—

Protoplasm.—This is the substance of which the living contents of the cell is composed. It is far more complex in its composition than cellulose, consisting of carbon, hydrogen, oxygen, and nitrogen, and some other elements, of which phosphorous and sulphur are the chief. It must not be regarded as a definite chemical compound, but rather a

[1] Schultze's solution:—Dissolve zinc in hydrochloric acid: permit the solution to evaporate in contact with metallic zinc until it has attained a syrupy consistence. Saturate the syrup with potassic iodide, and then add enough iodine to make a dark sherry-coloured solution. The object to be stained must be placed in a little water, and then some of the above solution added.

mixture of various compounds. It is variously acted upon by different chemical reagents. Iodine stains it brown, and concentrated sulphuric acid rose red, whilst it is also stained by magenta. It is soft and jelly-like in structure, never truly fluid. At times it is homogeneous and transparent, more often it is granular or frothy in appearance. There is always a quantity of water present, which, especially in the older cells, collects in drops or vacuoles. The protoplasm is the living part of the cell, and possesses considerable power of movement.

The movements of protoplasm may be grouped under two heads :—

1. Movements of protoplasmic masses destitute of a cell wall.

(*a*) Swimming by means of cilia, as in the case of Chlamydomonas (p. 1).

(*b*) Amœbiform movements, where a naked mass of protoplasm emits irregular projections (*pseudopodia*) at various parts of its surface ; the rest of the mass flowing after the processes. This is seen in the remarkable animal the Amœba, and is met with in some of the lower forms of plant life.

2. Movements of protoplasm within the cell wall.

In many cases the protoplasm contained within the cellulose wall shows a tendency to rotate or circulate in various directions through the cell, often carrying with it substances which may be embedded in it. This is especially well seen in the cells of many water plants. (See Fig. 19.)

In most living cells there is a **nucleus**, a rounded or oval structure embedded in the protoplasm. This is rendered more visible by staining with such a substance as hæmatoxylin ; it is then found to consist of—

(*a*) The **nuclear membrane**, a well-defined wall which separates it from the general mass of the protoplasm.

(*b*) A number of threads, sometimes forming a more or less tangled coil, which contain a deeply-stainable substance. This latter is the **chromatin**.

(*c*) The ground substance, **nuclear sap**, or **achromatin**, through which the threads are distributed.

The substance of the nucleus is proteid in nature, but contains, in addition to the carbon, hydrogen, oxygen, and nitrogen, a considerable amount of phosphorus.

Scattered through the protoplasm of many cells, and often congregated around the nucleus, are a large number of protoplasmic masses which are known as **plastids**. Some of these plastids have colouring matter of various kinds diffused through them, and are known as **chromoplasts**. They are to be seen very well in the pulp of a ripe Tomato, in the petals of many flowers, and in the roots of such plants as the Carrot.

In the interior of plants, where the light cannot penetrate, we frequently find **leukoplasts**. They are well seen in the young tubers of Potato and in the rhizome of an Iris, and are starch-builders, manufacturing the grains of reserve starch from the soluble hydrocarbons. In many parts of plants exposed to the light the plastids are permeated with a green colouring matter, and are known as **chloroplasts**.

Chlorophyll is the name of the material to whose presence the green colour of plants is due. In many lower forms of

plants it is diffused generally through the protoplasm, but in all higher plants it is restricted to the chloroplasts. The chlorophyll is soluble in alcohol, ether, chloroform, benzine, and essential oils and fats.

It is **produced under the influence of light,** except in the case of the germinating seeds of some Conifers and the fronds of Ferns, in which cases high temperature alone appears to be necessary for their formation.

If a growing plant be placed **in perfect darkness no chlorophyll will be formed**; the leaves and other organs which would naturally have a green colour, present a pale and sickly appearance. Such organs are said to be *etiolated*. An example is to be found in the leaf-stalks of Celery. In the natural state they are green, but when cultivated, earth is heaped up so as to remove them from the influence of the light. The result of this is to produce the white leaf-stalk of the edible varieties, this change of colour being accompanied by change of flavour.

FIG. 6.—Chloroplasts in cells of leaf of *Funaria hygrometrica*. *A*, chloroplasts with contained starch grains imbedded in the protoplasm of the cells. *B*, separated chloroplasts containing starch: *a*, *b*, young granules: *b'*, *b''*, chloroplasts dividing; *c*, *d*, *e*, old chloroplasts; *f*, granule swollen up by action of water; *g*, starch granules remaining after chlorophyll destroyed by action of water. (After Sachs.)

Chlorophyll plays a most important part in the plant economy, which we shall notice when we treat later on of the food supply of the plant. In the autumn, before the leaves fall, the chlorophyll becomes disorganised and decomposed, red and yellow colouring matters being formed in the chloroplasts. This gives rise to the autumn colouring of leaves.

Starch has the same percentage composition as cellulose, but appears to have a simpler molecule, its chemical formula being $C_6H_{10}O_5$. It differs from it, however, in many of its properties. It is insoluble in cold water, but swells up very strongly on the addition of boiling water, forming a paste. It is readily turned a dark blue by the addition of iodine. As

FIG. 7.—Various forms of starch grain from the Potato.

this blue colour, however, is removed by heat, the starch requires to be cold, or nearly so, for its production. Exposed to heat for some time, or to dilute sulphuric acid for a shorter period, starch is converted into dextrine, or British gum.

Starch occurs in the plant in the form of granules varying in their size. Amongst the smaller are those of Rice starch,

FIG. 8.—I. Starch grain from the Scarlet Runner. II. *a*, *b*, Starch grains from Rye. III. Starch grain from the stem of the Sarsaparilla (*Smilax sarsaparilla*).

which are frequently under $\frac{1}{5000}$ of an inch in diameter, whilst those of the "Tous-les-mois" are often as much as $\frac{1}{300}$ of an inch in length. In external form they vary very much, but they usually present a central portion, the hilum, or nucleus, round which the starch substance is arranged in concentric layers. Probably this striated appearance is due to a varying quantity of water in the different parts of the granule.

The size of the starch grains varies in the same plant. When first formed in the leaf it is known as **assimilation starch**: it is formed by the chloroplasts under the influence of light. The carbon dioxide of the atmosphere is decomposed, its carbon being combined with the elements of the water brought up to the leaf from the soil. These grains, thus formed in the leaf, are small. They are being constantly dissolved and carried away to those parts of the plant where reserve food is stored. In the protoplasm of the leaf cells there is present a ferment, **diastase,** which, acting upon the starch granules, dissolves them, converting them into a form of sugar. A similar action is produced by the ferment present in saliva. Thus the starch is being constantly removed from the leaves. When the sugar is conveyed to those parts of the plant where food is stored it is either stored up as sugar, as in the case of the Carrot and the Beet, or else it is, by the action of the leukoplasts, reconverted into starch. The grains thus formed, **reserve starch**, are as a rule much larger than the grains of assimilation starch formed in the leaves. The leukoplasts are closely allied to the chloroplasts, differing from them in containing no chlorophyll. If exposed to the light, however, they are often converted into true chloroplasts.

Fig. 9. — Starch grains from the latex of *Euphorbia splendens*.

Fig. 10.—Cell of endosperm of *Zea Mais*, Maize. The plates of protoplasm separating the polygonal starch grains. *a-g*, granules from germinating seed of Maize becoming dissolved and disintegrated. (After Sachs.)

The starch substance seems to be separable into two parts, which are allied if not identical in composition, but which

differ in properties. The one, known as *farinose*, or *starch cellulose*, appears to form the skeleton of the granule, and is either stained brown by iodine, or, as in some cases, remains unstained; whilst the other part, *granulose*, which forms 94 to 96 per cent. of the granule, is coloured blue.

Granulose is readily soluble in saliva, and is thus separated

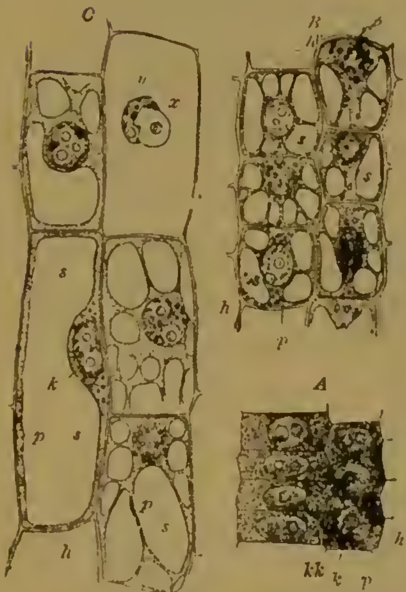

FIG. 11.—Cells from the root of *Fritillaria imperialis*. *A*, very young cell from near apex. *B*, from 2 mm. above the apex. *C*, from about 8 mm. above the apex; *h*, cell wall; *p*, protoplasm; *k*, nucleus; *kk*, nucleoli; *s*, vacuoles and cell-sap cavity. (After Sachs.)

FIG. 12.—Crystals of calcium oxalate in the cell wall. *Welwitschia mirabilis*. (After Sachs.)

from the skeleton. The same change takes place by the action of **diastase**, a substance occurring in germinating seeds, whereby the starch stored up in the seed as a food supply is rendered soluble.

Starch, then, constitutes one of the most important reserves of food laid up for future use by a plant. It must, however,

be clearly understood that the soluble substances out of which the plant is able, *in the first instance*, to make starch are formed in the green parts, and only under the influence of sufficient light. When the organic substance is once manufactured in this way it can undergo numerous changes within the plant, of which the formation of starch in the leaves or in underground parts is an example.

Cell Sap.—In the young cell the whole of the wall, with the protoplasm and other contents, is saturated with a watery fluid containing various mineral and other substances in solution. This constitutes the cell sap. As the cell increases in age this sap collects in drops (*vacuoles*), which gradually run together until the whole of the interior of the cell is filled with sap, presenting the appearance of being surrounded by two coats—viz., within, the layer of protoplasm: and without, the cell wall. This sap is most important, as it contains much of the food material of the plant.

In many cases the colours of flowers are due to the presence of various colouring matters dissolved in the sap. The same is true in the case of the root of the beet.

Raphides or Crystals.—Very often some of the mineral substances contained in the sap become crystallised out, and make their appearance either within the cell or in the wall.

FIG. 13.—Cell from the stem of *Aloë retusa*, with raphides.

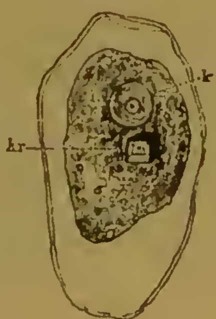

FIG. 14.—Crystalloid, *kr*, in a parenchymatous cell of the Potato tuber; *k*, nucleus.

In some plants the amount of these crystals is very great. In the Old-Man Cactus, as much as 80 per cent. of the dried tissue

consists of them. Professor Bailey found in a square inch of Locust bark, no thicker than writing paper, as many as a million and a half of these crystals. The root of Turkey Rhubarb contains so many as to give a gritty character to it when chewed. As a rule the raphides are found in cells where there are no other granular contents, but this is not universal. In chemical composition they consist of phosphate of calcium, or more often of oxalate of calcium (Fig. 12). Carbonate or sulphate of calcium is sometimes met with. In shape they are either cubical, octohedral, or needle-like (hence the name of *raphides*, from the Greek name for a needle).

Crystalloids.—In some cells, especially those of fatty seeds like the Brazil nut, bodies are found which are crystal-like in appearance, but instead of being mineral in composition, consist of proteinaceous or nitrogenous material closely allied to protoplasm. They are insoluble in water, but break up in a peculiar manner so as to appear to be composed of several layers. They stain with iodine, which crystals will not.

Aleurone Grains are minute rounded grains found in the

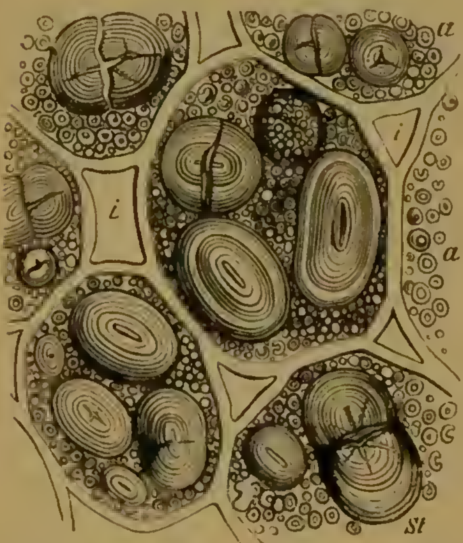

FIG. 15.—Cells of cotyledon of *Pisum sativum*, Pea. *St*, starch granules with central hilum and concentrated striæ; *a*, granules of aleurone; *i*, intercellular spaces. (After Sachs.)

FIG. 16.—Sphere crystals of inuline in a parenchymatous cell from a tuber of the Dahlia preserved in alcohol, after addition of nitri acid.

cells of many seeds. They often contain crystalloids. They are soluble in caustic potash. They are often embedded

in oil, and appear to be used as food reservoirs by the plant.

Inulin is a peculiar substance found in the roots of Compositæ, and now and then in stems. It is very closely related to starch and sugar, and in the living plant is only found in solution in the sap; but by the addition of alcohol or glycerine it separates out, either in a frothy condition or as beautiful spherical masses known as *sphere crystals*.

CHAPTER IV.

CELL GROWTH, SHAPE, FORMATION, AND TISSUES.

THE cell protoplasm and the cell wall both grow by the addition of fresh substance added to that previously present. As regards the protoplasm, simple bodies are caused to enter into complex chemical combinations, and ultimately there become incorporated in the living substance. In the case of the cell wall, growth is due to the activity of the protoplasm, fresh molecules of cellulose are either intercalated amongst those already present, or they are, so to speak, plastered on to

FIG. 17.—I. Spherical cell from the flesh of the Peach. II. Ellipsoidal cell from the flesh of the Peach. III. Hour glass-shaped cell from the flesh of the Peach.

the surface of the wall already present. The result of the process is that the wall may grow both in surface and in thickness, and various patterns, often of great complexity, may be produced upon it. But the continuous growth depends entirely upon the activity of the living substance, the protoplasm, which determines entirely the character of the individual cells of which a plant is made up.

When a cell grows it very frequently happens that the increase in size does not take place equally in all directions, and thus produces a change in the shape of the cell. The normal form is more or less spherical: this, however, is rarely preserved except in the case of unicellular plants. If the wall grows more vigorously at the two extremities than at the sides, the cell will become **oval** or **elliptical** (Fig. 17), then **elongated** (Fig. 19), and lastly **fusiform** or **spindle-shaped** (Fig. 18).

FIG. 18.—I. Fusiform cell from the wood of the Spruce Fir, with bordered pits. II. Fusiform bast-fibre of the Larch.

FIG. 19.—Circulation of protoplasm in an elongated cell of the Celandine: *k*, the nucleus with a nucleolus. The arrows indicate the direction of the currents.

On the other hand, if a very vigorous growth takes place at certain parts whilst the rest of the cell wall is but slightly developed, several protuberances will be produced upon the surface, and a **stellate** or **star-shaped** cell is formed (Fig. 20).

Another cause modifying the shape of individual cells is to be found in their mutual pressure the one upon the other during growth. By this means they may become flattened or tabular (Fig. 21), or polyhedral (Fig. 22).

Other forms of cells are shown in Figs. 23, 24, and 25.

At first the cell wall appears as a thin layer of cellulose perfectly permeable to liquids. In some cells but little thickening takes place during growth; in many others, however, very

FIG. 20.—Stellate cell from the horizontal septum of the air-passages of the Flowering Rush (*Butomus umbellatus*).

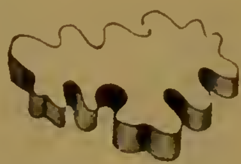

FIG. 21.—Tabular cell from the epidermis of *Callitriche*.

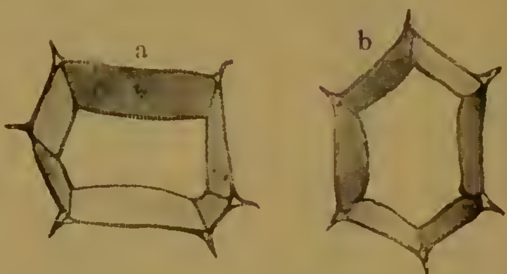

FIG. 22.—Polyhedral cell from the pith of *Acacia lophantha*: *a*, seen in transverse; *b*, in longitudinal section.

FIG. 23.—I. Disc-shaped cell; a unicellular Alga, *Coscinodiscus*. II. Crescent-shaped cell of a stoma (guard-cell).

FIG. 24.—Tetrahedral cells; spore of a Fern in various positions.

soon layers of secondary deposit are formed lining their interior surfaces. At first these layers are complete and continuous like the original coat, but soon they are developed but slightly

or not at all at certain points, thus causing depressions or **pits** in their substance. The pits thus produced in the contiguous layers correspond with one another, canals are gradually formed leading towards the centre of the cell cavity and across the thin membrane, the protoplasm of one cell may be directly continuous with that of the adjoining one by means of very fine connecting protoplasmic strands.

Such cells, when seen under a microscope, transmit the light differently through their pore canals and through the thickened walls, and hence they present a pitted or dotted appearance, as though pierced by a number of holes (Fig. 26). These cells are known as **pitted** or **dotted cells.**

FIG. 25.—Branched bast-cell of the Larch.

FIG. 26.—Section through endosperm of *Antholyza*. Parenchyma with thickened cell walls; *p*, pores seen from their end.

In other cases the secondary deposit takes the form of a spiral band round the wall, thus producing a **spiral** cell (Fig. 28); or else it is deposited as separate rings, when an **annular** cell is formed (Fig. 29). When the thickening is arranged in an irregular manner, producing a perfect network over the wall, the cell is said to be **reticulated**.

Very often there is in the cell a gradual passage from a spiral to an annular or reticulated marking (Fig. 31). At other times there is a spiral or reticulate marking in addition to the pits or dots (Fig. 32).

Fig. 33 shows another form of thickening, known as **scalariform**, or ladder-like. In this case the secondary deposit is arranged in transverse layers like the rungs of a ladder. Such cells are well seen in the stems of Ferns.

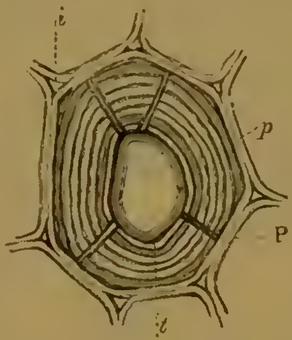

FIG. 27.—Transverse section of a cell of the pith of *Clematis vitalba* : *p*, primary cell wall ; *t*, innermost thickening layer ; P, pore-canal ; *i*, intercellular space.

FIG. 28.—A spiral cell from a Cactus, *Opuntia Tuna*, with strongly thickened spiral band.

A very important form of pitted cell is met with, especially in the wood of the Fir trees and their allies. In these cases the pit is *funnel-shaped*, being wide on the outside and gradually tapering till it forms a tube or pore canal leading into the centre of the cell.

FIG. 29. — Annular cell from *Arundo donax*, with strongly thickened rings placed at different distances and different angles.

FIG. 30. — Reticulately thickened cell of the Touch-me-not (*Impatiens noli-me-tangere*).

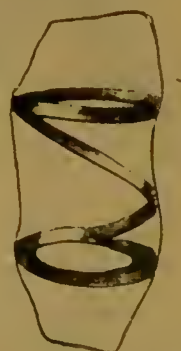

FIG. 31.—Annular cell from an *Opuntia*, with rings passing over into a spiral band.

On examining these cells by means of a microscope, they present the appearance of a central pit surrounded by a border, and they are called **cells with bordered pits**. This appearance

is caused by a varying amount of light being transmitted through the central pore which forms the pit, and the funnel shaped upper portion which forms the border.

Besides these appearances due to secondary deposit, there is, especially in older cells, a striation or stratification of the cell wall, which appears to be due to the varying amount of water in the different parts of the wall.

FIG. 32.—Piece of a reticulately pitted tracheide from the Lime (*Tilia grandifolia*).

FIG. 33.—Scalariform cell from the underground stem of the Brake (*Pteris aquilina*).

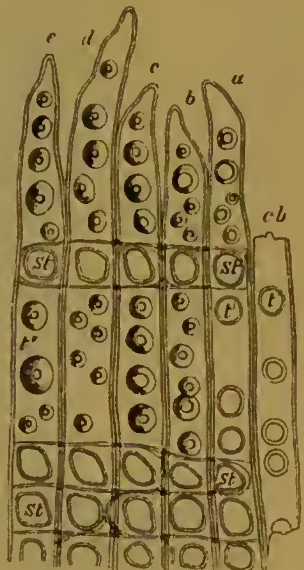

FIG. 34.—Longitudinal section of wood of *Pinus sylvestris*. Bordered pits, *t t' t''*, increasing in age; *a–e*, wood cells, *e*, eldest, *a*, youngest; *cb*, wood cells of cambium; *st*, large pits, where medullary rays touch wood cells. (After Sachs.)

A very important modification of cells is brought about by the fusion of adjacent cells to form **vessels**. Such vessels occur largely in the wood and in the bast of many plants. The vessels of the wood are most often produced by the more or less complete absorption of the cross walls separating the cavities of a row of contiguous cells. Thus a tube is formed that may reach the length of many centimetres. The vessels

of the bast are not so complete as those in the wood, as the separating cross walls are only perforated by a number of fine holes in a sieve-like manner. These bast vessels are known as **sieve-tubes**.

These vessels form part of the conducting elements of the plant. Those of the wood are mainly concerned (together with the tracheids) with the transport of water, whilst the sieve-tubes serve as the channels through which some of the manufactured food substances of a nitrogenous character are transported to the spots where they are needed for consumption and growth.

I.

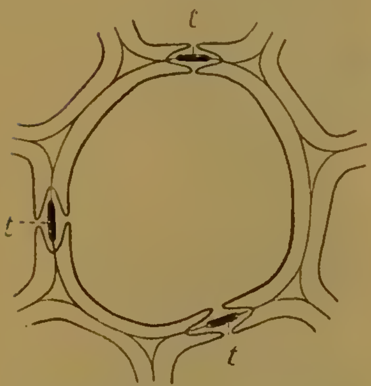

FIG. 35.—Transverse section through tracheïde of wood of *Pinus*, showing three bordered pits with their torus (t) in the centre.

II.

FIG. 36.—I. Sieve tube from the White Bryony (*Bryonia dioica*), the horizontal partition walls with peculiar thickenings. II. Transverse section of a sieve-disc, the upper part represented with the thickening substance, which takes the form of wart-like elevations; the lower part without it.

I. II.

FIG. 37.—I. Portion of a scalariform vessel from the Brake (*Pteris aquilina*): *s*, *s*, the transverse division wall broken through in a reticulate manner. II. Pitted vascular cell from the stem of a Grass, *Phragmites communis*, with numerous small bordered pits.

Bast tubes or **bast fibres** are generally more pointed and sometimes branching (Fig. 38).

Other forms of vessels are those known as **vesicular vessels** and **laticiferous vessels.** The former consist of elongated cells containing a milky juice and bundles of needle-shaped crystals.

Laticiferous vessels are tubes more or less branching, often forming a complete network, and containing a fluid known as *latex*, which is often milky, sometimes coloured, and varies in its composition in different plants. Sometimes, however, single *cells*, growing to an enormous size, and branching freely in the plant, take the place of the laticiferous *vessels*.

FIG. 38. — Fusiform bast fibre of the Larch.

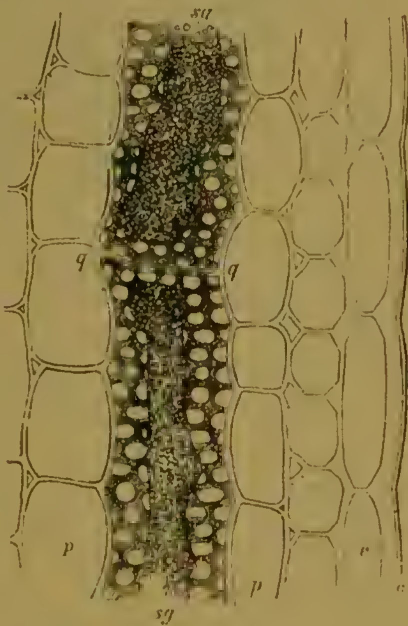

FIG. 39.—Vesicular vessel in longitudinal section of scale of bulb of Onion (*Allium Cepa*): *e*, epidermis with cuticle (*c*); *p*, parenchyma; *sg*, coagulated contents contracted to show the porous walls (*q*). (After Sachs.)

Cells do not grow indefinitely; the size of the adult cell varies. **Prosenchymatous cells** vary from $\frac{1}{45}$ to $\frac{1}{12}$ of an inch in length, and from $\frac{1}{1500}$ to $\frac{1}{3000}$ of an inch in diameter. **Parenchymatous cells** vary as a rule from $\frac{1}{250}$ to $\frac{1}{1250}$ of an inch in diameter, whilst some in the pith of plants, in succulent parts, and in water plants, are as much as $\frac{1}{30}$ or even $\frac{1}{10}$ of an inch in diameter.

It may often be seen, especially in young tissues near the growing-points, that the cells are undergoing division, so as to increase in number, and it is by this means that the organs of plants finally increase in size. There are several modes by means of which new cells are produced, but in the

formation of the vegetative cells of higher plants it is usually by means of **cell-division.** The first part of the cell to show any changes is the nucleus. The tangled threads of the chromatin become somewhat disentangled and at the same time they stain more readily. Finally they break up into a number of segments or **chromosomes,** which arrange themselves across the equator of the nucleus forming the **nuclear plate.**

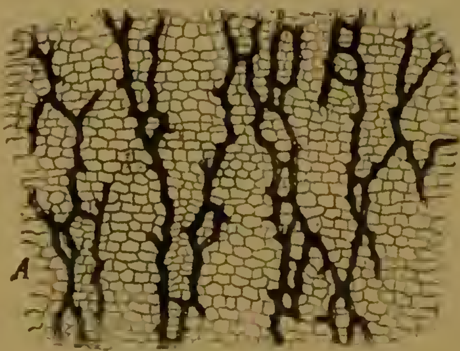

FIG. 40.—Transverse section of phlöem of root of *Scorzonera hispanica*, showing branching and anastomosing laticiferous vessels.

Meanwhile radiations appear in the protoplasm at two opposite sides of the nucleus, and these finally are continued through the nucleus, so as to give rise to what is called the **spindle.** During its formation the nuclear membrane generally disappears. The chromosomes divide longitudinally into halves, and the two groups thus formed migrate towards the poles forming the **diaster** stage. The chromosomes now unite into a tangled thread, and two daughter nuclei are thus formed, each surrounded by a nuclear membrane. This division of the nucleus is spoken of as **karyokinensis, mitosis,** or **indirect nuclear division.**

The division of cell is brought about by the thickening of the rays of the spindle in the equatorial plane of the mother cell; and thus a new wall is formed, dividing the original cell into two.

When fresh cells are thus formed by cell-division they do not, as a rule, separate, but remain united, and thus form **cell tissues.** Although the cellulose wall completely surrounds the protoplasm in the young cells, yet in many cases (probably in all cases where there are living cells) it has been shown that there is a continuity of protoplasm through the tissues. This is brought about by means of thin threads of protoplasmic substance, which persist whilst the cell-plate is being formed.

This has been seen in the endosperm of many seeds, in the contractile organ at the base of the leaves of the sensitive plants, in epidermal cells and other places.

Cell tissues may be grouped according to their function, position in the plant, and structure.

According to their function, we divide them into **meristem,** which is tissue consisting of vitally active cells which are capable of dividing and growing; and **permanent tissue,** where the cells are no longer able to divide.

According to their position in the plant, we group them into—**Epidermal tissues,** those which form the external covering of the organs, shutting their

inner tissues off from the outer world. **Fibro-vascular tissues**, which are arranged in strands, consisting of fibres, or elongated cells, and vessels. They form the conducting tissues of the plant, conveying the sap to the various parts where it is needed. **Ground tissues**. This term is applied to all the rest of the plant body.

FIG. 41.—Division of the nucleus in a cell of a root node of *Chara fœtida*. Stage showing cell-plate and connecting threads. (Johow.)

FIG. 41*a*.—Nuclear division in end cell of a leaf of *Chara fœtida*, showing newly formed cell-wall. (Johow.)

According to their structure, we group tissues into—**Prosenchyma**, those tissues which consist of elongated cells, which usually more or less overlap one another. **Parenchyma**, those tissues which are formed of shorter cells placed end to end.

Sometimes the term **sclerenchyma** is used to denote either prosenchymatous or parenchymatous tissues, where the walls of the cells have become very thick and hard, and often dark-coloured.

CHAPTER V.

GERMINATION, ROOT GROWTH, STRUCTURE, AND FUNCTIONS.

If a living seed be placed in the soil and be supplied with moisture and warmth, and exposed to fresh air, germination will ensue. The range of temperature between which this is

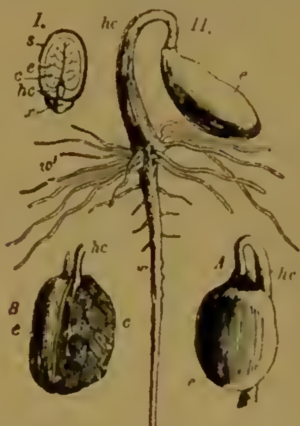

Fig. 42.—*Ricinus communis.* *I.* longitudinal section of ripe seed. *II.* germinating seed, the cotyledons still within the spermoderm, shown more distinctly in *A* and *B*: *s*, spermoderm; *e*, endosperm; *c*, cotyledon; *hc*, hypocotyledonary portion of axis; *w*, primary root; *w'*, lateral rootlets; *r*, the caruncle (or aril), a peculiar appendage to the seeds of *Euphorbiaceæ*. (After Sachs.)

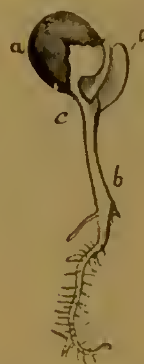

Fig. 43.—Germinating seed of cabbage: *b*, axis; *c*, *d*, the two cotyledons, which have risen above the soil, the testa *a* not being yet completely thrown off.

possible varies with different plants, but it may be stated generally as being between 5° or 6° C. and 40° C.

Either the roots at once lengthen and grow out through the micropyle, or, which is more often the case, the hypocotyl becomes elongated, pushing the end of the root before it out of the seed.

If we sow in some soil specimens of the following seeds—Broad Bean, Acorn, Beech, Cress, Cabbage, Castor Oil, Pine,

Date, and Wheat—and watch the germination as it takes place, we shall find that there is a great difference with regard to the growth and development of the cotyledon during the process.

FIG. 44.—Seeds of *Pinus Pinea* in different stages of germination. *I*, ripe seed in longitudinal section: *s* spermoderm; *e*, endosperm; *w*, radicle of embryo; *c*, the cotyledons; *y*, the micropyle end of seed, with the rootlet directed towards it. *II*, germination commencing: *A*. spermoderm, *s*, ruptured, and rootlet, *w*, protruding; *r*, red membrane inside spermoderm; *x*, ruptured embryo sac: *B*, portion of spermoderm removed; *c*, endosperm: *C*, longitudinal section; *c*, cotyledons: *D*, transverse section. *III*, germination complete, the cotyledons, *c*, unfolding, and the hypocotyledonary part of stem, *hc*, elongated, the main root, *w*, developing lateral rootlets, *w*. (After Sachs.)

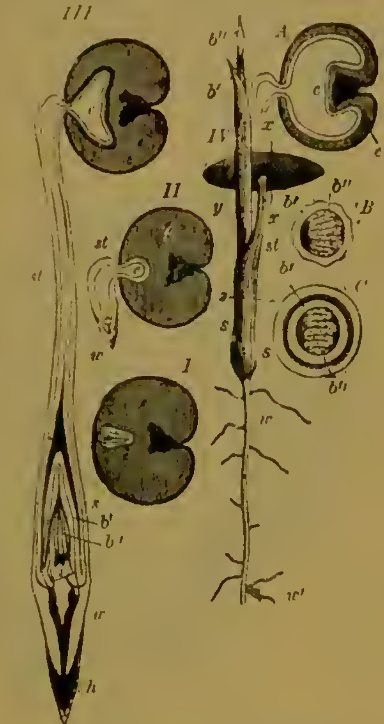

FIG. 45.—Germination of *Phœnix dactylifera*. *I*, transverse section of seed before germination. *II*, *III*, *IV*, different stages of germination. *A*, transverse section of seed at *x*, *x*, in *IV*: *B*, at *xy*; *C*, at *zz*. The following letters refer to all the figures: *e*, endosperm; *s*, sheath of cotyledon; *st*, its stalk; *c*, apex, forming an organ of absorption by which the endosperm is entirely removed, the growing end occupying the place of the absorbed endosperm; *w*, primary root; *w'*, secondary root; *b'*, *b''*, leaves succeeding the cotyledon; *b'''*, the first foliage leaf; *h*, pileorhiza. In *B*, *C*, the folded lamina is seen cut across. (After Sachs.)

In *exalbuminous* seeds, where the cotyledons are thick and fleshy, as in the Bean (Fig. 1) and Acorn, they remain within the seed during germination, finally perishing after the food-

material contained in them has been used up for the growth of the embryo. In the case of the Cress, Cabbage, and Beech we have an *exalbuminous* seed where the cotyledons are thin, and here they rise out of the soil to form the first leaves, carrying the testa with them (Fig. 43). The Castor Oil plant has an *albuminous* seed ; in this case the cotyledons are not liberated until after the *endosperm* has been all absorbed (Fig. 42). In the case of the Pine we have an analogous growth (Fig. 44),

FIG. 40.—Longitudinal section of fruit of *Zea Mais*. *c*, pericarp ; *n*, remains of the stigma ; *fs*, base of the fruit ; *eg*, hard yellowish part of endosperm : *ew*, white softer portion of endosperm ; *sc*, scutellum (cotyledon) of embryo : *ss*, its apex ; *e*, its epidermis ; *k*, plumule ; *w* (below), the main root ; *ws*, sheath covering main root ; *w* (above), lateral rootlets springing from the first internode of the stem, *st*. (After Sachs.)

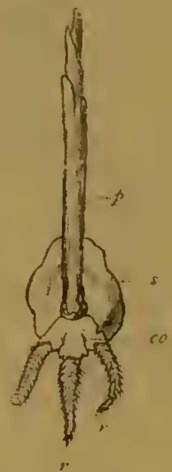

FIG. 47.—Germinating embryo of Oat (the endosperm removed). *p*, the plumule ; *s*, the scutellum ; *r*, *r*, the rootlets : *co*, the coleorhiza.

the cotyledons (which are numerous) appearing above ground after the absorption of the albumen, the peculiarity here being the development of *chlorophyll* in the cotyledons before they rise above the surface. All these, with the exception of the Pine, are *dicotyledonous* seeds. The remaining two illustrate the germination of *monocotyledons*. In the Date Palm (Fig. 45) the lower part of the cotyledon lengthens, pushing the root

and plumule out of the seed, whilst the rest of it remains in contact with the albumen, absorbing it.

In the Wheat (Fig. 46) the cotyledon is developed to form a plate where it is in contact with the endosperm, and is known as the **scutellum**. This serves the purpose of absorbing the albumen. In this case there is at once a growth of the root causing a rupture of the sheath surrounding it, which remains

Fig. 48.—Germinating Bean: *a*, *b*, cotyledons; *c*, *d*, leaves; *e*, terminal bud; *h*, primary root; *g*, lateral roots.

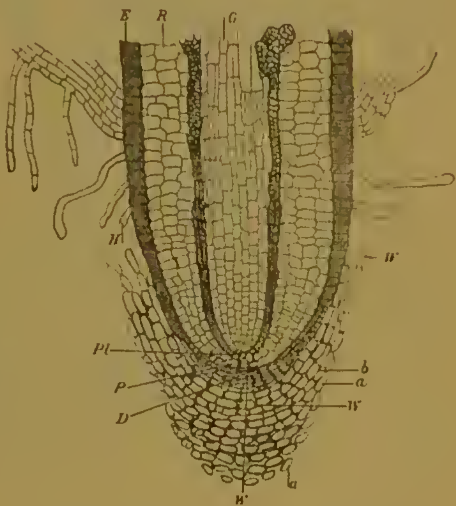

Fig. 49.—*G*, central cylinder, consisting of pith, vascular bundles, and pericycle; *R*, cortex; *E*, piliferous layer; *W*, root-cap.

attached to the axis forming the **coleorhiza** (Fig. 47). In some few monocotyledonous plants, where there are exalbuminous seeds (as in the natural orders Naiadaceæ, Alismaceæ, etc.), the cotyledon is freed from the integuments, and is raised up through the soil.

When the cotyledons remain beneath the soil they are said to be **hypogeal**, when they rise above **epigeal**.

There is also a great difference between dicotyledons and monocotyledons with regard to the formation of the young root. In dicotyledons the radicle is directly prolonged, and no branching takes place until after the young root has left the seed (Fig. 48), so that the first root is a direct prolongation of

the radicle, and is known as a **normal** or **tap** root. Such a mode of root development is called **exorhizal.** In monocotyledons, on the other hand, there is a branching within the seed (Fig. 47), and the radicle is often not directly produced. Such roots are known as **adventitious,** and the growth is said to be **endorhizal.**

The term *adventitious* is applied to all roots which are not developed by the direct growth of the radicle: hence in dicotyledons adventitious roots may be developed later on from various parts of the plants (as from stem, as seen in the Ivy, etc.), so that it is only the first-formed roots which are always normal in this group.

ROOT STRUCTURE.

Even whilst the radicle is within the seed a change of shape and condition has come over some of the cells, which, however, is more apparent after the young root has commenced to grow (Fig. 49). The outer layer of cells becomes more or less flattened, forming a complete protective coat known as the **epidermis.** At the extremity the cells are thickened in such a manner as to produce what is known as the root-cap or **pileorhiza,** which is intended to protect the growing extremity of the root during its prolongation. Just behind the root-cap there is a mass of meristem tissue, which forms the growing point of the root. This by the constant subdivision of its cells produces on its outer sides additions to the root-cap, thus making up for portions that have become worn off by the growth of the root, whilst on its inner side it forms fresh tissue, thus causing the root to increase in length. Roots, then, increase in length only by growth near the apex. In transverse section the mass of the young root, within the epidermis, is seen to consist of a number of parenchyma cells, forming the **ground** or **fundamental tissue.**

The **fibro-vascular tissue** is in the centre of the root, and consists of groups of two different kinds alternating with one another (Fig. 50). Some of the groups consist chiefly of fibres and vessels with more or less lignified walls, and they form the xylem (*g*); others have no true vessels, but sieve tubes are abundant they form the phloëm (*p*). The number of xylem and phloëm groups varies in different plants. Thus, in the Wallflower, there are two primary groups of each kind, and we speak of the arrangement as a **diarch** bundle. In the

Scarlet-runner four primary groups, or a **tetrarch** bundle. In the Lily a large number of groups, or a **polyarch** bundle.

Round the xylem and phloëm groups there is a layer of thin walled cells, the **pericycle** or **pericambium** (*pc*). Branches of the root are formed by outgrowths of the pericycle

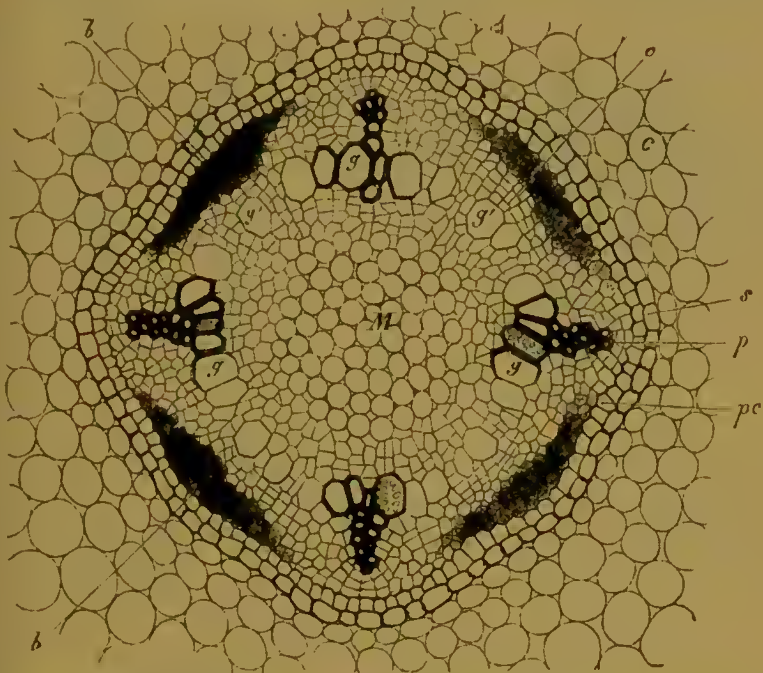

FIG. 50.—Transverse section of root of *Phaseolus*. M, pith; *s*, endodermis or sheath of fibro-vascular bundles, with parenchyma of the ground tissue externally; *pc*, pericambium layer; *b*, primary phloëm of bast fibres; *g*, primary xylem, with vessels; *c*, cambium. (After Sachs.)

which push their way out through the adjacent tissue, and thus form rootlets, which repeat the structure of the original root (Fig. 51).

Outside the pericycle is the layer of **endodermis**, or **bundle sheath** (*c*). The cells which form it can easily be recognised when seen under the microscope, as they present a dark mark where they touch one another. This is owing to the fact that the lateral walls, where the cells are in contact, are suberised; where, on the other hand, they are in contact with the ground tissue without and with the pericycle within, the walls retain their original cellulose structure. The whole of the mass of tissue contained within the bundle-sheath is spoken of as the

central cylinder, or **stele.** The central part of the stele is occupied by parenchymatous cells forming the **pith,** or **medulla** (M). In the young root, the **protoxylem,** or first xylem formed, is always towards the outer part of the cylinder, fresh xylem being developed towards the centre until, in many cases, the centre of the cylinder is filled up with xylem cells.

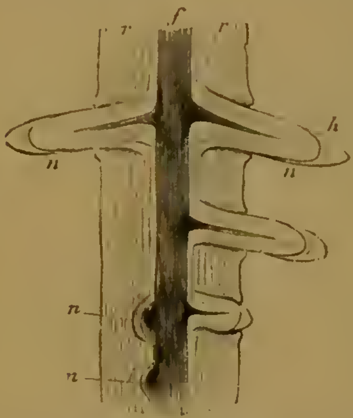

FIG. 51.—Longitudinal section of main root of *Vicia Faba. r, r,* cortex of main root ; *f,* fibro-vascular bundles ; *n, n,* lateral rootlets developing from pericambium, and breaking through cortical tissue ; *h,* pileorhiza of side rootlets. (After Prantl.)

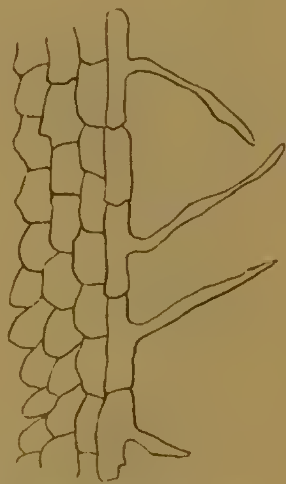

FIG. 52.—Epidermis of root with hairs.

Such a stele, where the xylem and phloëm portions are placed side by side, is spoken of as **radial.**

Roots increase in thickness by the formation of a layer of meristem tissue known as **cambium.** This is first produced just within the phloëm groups by a division of the cells of the ground tissue between the xylem strands.

These cambium masses soon meet in the pericycle, just outside the xylem groups. The cells of the cambium undergo division, producing xylem on the inner and phloëm on the outer side. Thus, whilst the primary xylem is developed from without inwards, the secondary xylem is developed from within outwards.

Many of the epidermis cells near the apex of the main root and of its branches are produced into delicate prolongations, the **root hairs.** These are always developed close behind the growing point, and extend for a short distance up the root. They are the true absorbtive parts of the roots. They bring the roots into very close and intimate relation with the soil. If a young plant be carefully removed from the ground it is found that a considerable quantity of soil clings to the lower part of the root. This is held in position by the hairs.

In the older parts of the root, the epidermis disappears, and is replaced by a cuticularised **cortical** layer, or **exodermis,** from the ground tissue.

FORMS OF ROOTS.

There are certain terms which are used in the description of the form of the root. When it is broad at its base and tapers toward the apex, as in the Carrot (Fig. 53) or Monks-

FIG. 53. Conical root of the Carrot.

FIG. 54. Fusiform root of the Radish.

FIG. 55. Napiform root of the Radish.

FIG. 56. Fibrous root of a grass.

hood, it is **conical.** When it is broadest in the centre and tapers towards the two ends, as in the Radish (Fig. 54), it is **fusiform,** or spindle-shaped. When it has become somewhat globular with a tapering extremity, as in the Turnip, or some

FIG. 57.—Double tuber, *a*, *b*, of *Orchis Morio.*

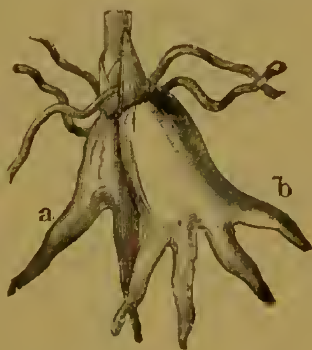

FIG. 58.—Double palmate tuber, *a*, *b*, of *Orchis odoratissima.*

varieties of Radish (Fig. 55), it is said to be **napiform**; whilst the term **placentiform** is applied to it if the tapering apex be absent, as in the Sow-bread. If a number of slender branches

be given off, as in the Grass (Fig. 56), the root is **fibrous.** When some of these fibres become swollen in an egg-shaped manner, as in *Orchis Morio* (Fig. 57), the term **tuberculated** is

FIG. 59.—Tuberous fasciculated root of the Dahlia.

FIG. 60.—Nodulose root of *Spiræa filipendula.*

employed; whilst if the tuber is divided so as somewhat to resemble the fingers of a hand outstretched as in *Orchis odoratissima* (Fig. 58), it is called **palmate.**

The term **fasciculated**, or tufted, is used where there are a number of tubercles or fleshy branches arranged in a bunch, as in the Dahlia (Fig. 59).

When the fibres are enlarged only at their extremities, as in the Dropwort (Fig. 60), the root is **nodulose**, or knotted; whilst if there be several swellings arranged like beads on a necklace, as in *Pelargonium triste*, it is said to be **moniliform**, or necklace-shaped.

In Ipecacuanha the root is called **annulated**, it being marked with several ring-like expansions upon its surface.

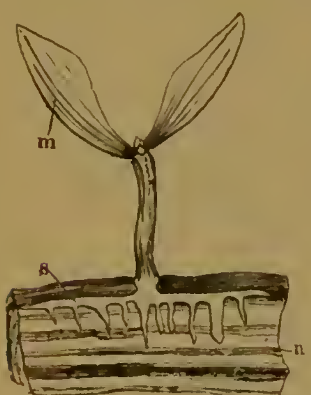

FIG. 61.—*n*, a piece of branch of an Apple tree cut through lengthwise, into which a young Mistletoe plant, *m*, has driven its sucking roots, *s*.

ROOT FUNCTIONS.

1. The root is a principal **organ of support**, tending to hold the plant fixed in the soil or other situation in which it may be growing.

2. It is an **organ for the absorption of food.**

This raises three questions, viz. the source of the food, the nature of the food, and the manner of its introduction into the plant.

A. *The Source of the Food* The roots, as a rule, enter the ground, and hence receive the plant-nourishment from that source. In the case of some aërial plants the roots absorb the food with the moisture present in the air, whilst in the case of many parasites, as the Mistletoe (Fig. 61), the sucking roots penetrate into the stem of the plant upon which it grows, thus obtaining their nourishment second-hand.

B. *Nature of the Food.*—A chemical analysis of the substance of a plant shows it to be composed of the following elements:—

Carbon, C.	Phosphorus, P.	Potassium, K.
Hydrogen, H.	(Silicon, Si.)	Calcium, Ca.
Oxygen, O.	(Chlorine. Cl.)	Magnesium, Mg.
Nitrogen, N.		Iron, Fe.
Sulphur, S.		(Sodium, Na.)

The five placed in the first column are sometimes called the organic elements, as they are required for the building up of the protoplasm and cellulose. Those placed in brackets are not so necessary or so universally met with as the rest.

Since, then, the plant body is built up of these elements, it is evident that they must enter into the composition of its food. They are not, however, absorbed in their elementary condition, being obtained from various compounds which contain them.

Carbon is obtained by green plants from **carbon dioxide**, called also carbonic anhydride, and formerly known as carbonic acid gas, CO_2, a gaseous compound of carbon and oxygen; perhaps partly by means of the roots; but especially, as we shall see later on, through the pores of the leaves, these pores performing the part of mouths for the plant. Carbon is one of the most important substances required, building up portions of all the plant-tissues, and usually forming one-half of the dried plant by weight.

Hydrogen, another element present in every organic compound, is obtained from **water**, H_2O, which is taken up in large quantities by the roots.

Oxygen.—The sources of this element are to some extent the two compounds H_2O and CO_2 already noted, and also the various **oxygen salts** of the metals, such as sulphates, phosphates, nitrates, etc. Besides this, the free oxygen of the atmosphere enters the plant, combining with the substance, as we shall have to notice further on under the head of Respiration.

Nitrogen, which is an essential element of protoplasm, the albuminoids, and allied bodies, is obtained from various **nitrates**, that is, compounds of nitric acid, HNO_3, with metals. It was formerly thought that ammonia, NH_3, a substance produced by the decomposition of animals, was an efficient source of nitrogen for the plant. Recent researches, however, have demonstrated that it is first oxidized into nitrites, *i.e.* compounds of nitrous acid, HNO_2, and then into nitrates. This is accomplished by the action of certain bacteria which are present in the soil. All the higher plants appear only to be able to obtain their nitrogen from nitrates, with the exception, however, of carnivorous plants (page 88), which obtain a portion of their nitrogen from animal substances.

Although nitrogen exists to a very large extent free in the atmosphere, most plants do not appear to be able to take advantage of it. Recently, however, we learn from the investigations of Hellriegel in Berlin, and Gilbert and Lawes at Rothamsted, that many leguminous plants possess the power of fixing the atmospheric nitrogen and using it for food. If the roots of such a plant as a Scarlet Runner, Clover, or Lupin are examined, they are generally found to be provided with little nodules or tubercules. These consist of masses of bacteria, which fix the nitrogen into the soil so that it can be utilised. It is found that if such leguminous plants are grown in a soil and then removed, they actually leave the soil richer in nitrates than it was before. Experiments with plants of other orders have failed to show any such fixation.

Sulphur is taken up as **sulphates**, that is, salts of sulphuric acid, H_2SO_4; probably chiefly calcium sulphate or gypsum, $CaSO_4$. This element also is required for the protoplasm and albuminoids.

Phosphorus is obtained from **phosphates**, principally calcium phosphate, Ca_32PO_4.

Silicon is taken in as **silica**, SiO_2, or as silicates, which are often largely present in the soil; whilst the sources of **chlorine** are the **chlorides** of the various metals, especially of sodium, the chloride of which is common salt. The metals mentioned above are all obtained as salts combined with the acids we have noticed.

c. Method of Introduction of the Food Substances into the Plant. Before any **food** can be absorbed it is necessary for it to be **in a state of solution.** The water present in the soil dissolves the various food materials, and thus brings them into a fit state to be taken.

The outside surface of the root is entire, not perforated by holes, hence the solution of food has to be absorbed into the cells of the plant itself. This is accomplished by means of the process of **osmosis**. If two liquids be separated by a membrane permeable to both, they will flow through it and intermingle.

This can be very easily demonstrated by means of a simple experiment. If a vessel is closed below by a piece of bladder, whilst a tube is tightly fastened in the neck (Fig. 62), and if a concentrated solution of cupric sulphate is placed in the vessel so that it stands a short way up the tube, and then the whole apparatus is plunged into a vessel of water as shown in the diagram, the two liquids will interchange, some of the cupric sulphate passing through the bladder into the outer water,

whilst some of the latter enters the vessel. The two liquids do not, however, flow with equal rapidity. The law in all such cases is that the denser liquid flows more slowly than the less concentrated. As cupric sulphate solution is denser than water, a larger amount of the latter passes through the membrane than the former, and therefore the liquid will rise in the glass tube. The passage inwards is called **endosmose**, whilst that outwards is termed **exosmose**. Sugar syrup may be used in the above experiment instead of cupric sulphate.

Fig. 62.—Apparatus for measuring osmose: *b*, a vessel filled with cupric sulphate closed below by a permeable membrane, and placed in a vessel of water. As the water passes through the bladder to mingle with the cupric sulphate, the level of the fluid will rise in the tube *r* in connection with the vessel *b*, but will fall at *n* in the outer vessel.

Now let us suppose the membrane to be of such a nature that whilst it would allow water to pass through, the dissolved substance, which we can suppose to be sugar, is unable so to traverse it. Then we shall have a flow of water into the sugary liquid, which will thus rise in the apparatus till the pressure produced by the column of liquid in the tube is sufficient to prevent any more water from entering the bladder. Now, we have something very like this in the root. Within the cells there is sap containing soluble organic substances, without there is the water with very small amounts of mineral substances in solution.

The protoplasm serves as the membrane between the sap and the outside water. The cell wall merely acts as a support for the protoplasm, for it very easily allows water and substances in solution to traverse its substance. Hence water passes from without into the sap contained within the protoplasm. The inner cells behave in the same way with regard to the cells situated outside them, and thus there is set up a flow of water into the interior of the root. Here the water joins the current that is kept passing up to the leaves. This latter current is maintained by forces that are at present obscure, though, in the first instance, no doubt the osmotic properties of the root cells just outlined above are concerned with starting it in the young plant, and with supplying the conditions for its continuance in the older stages of its life.

The *passage* of the current of sap up the plant is mainly

confined to the woody cells and vessels, whilst the actual *absorption* of liquid from the soil is most active in the root-hairs.

The various food materials are not, however, taken up indiscriminately by the plants. It is found, if plants are grown in water containing equal amounts of the salts necessary for food, that the quantities removed are very different.

There is what is known as **selective power**, each plant removing from the soil those substances which are more especially necessary for its life, leaving other foods behind. Thus leguminous plants remove especially lime salts: potatoes and turnips, compounds of potash; cereals and grasses, silica; and so on.

If the same plant be grown year after year in the same soil it gradually impoverishes the ground, whilst food materials needful for other plants will be accumulated. Hence is brought about what is known as rotation of crops—that is, growing a well-chosen selection of plants in succeeding years in the same soil.

The exact plan of rotation varies with the nature of the soil and the plants desired to be grown. The following is an example of what is known as the Norfolk or four-course rotation :—

1	2	3	4
Fallow, Turnips and Swedes	Barley	Clover	Wheat

That is, the farm will be broken up into four portions. The first will undergo thorough tillage and be planted with root crops, which need especially potash and lime, and, having short roots, take their food near the surface, or are surface-feeders. Division No. 2 has barley, which takes up very little lime and potash but much silica, and is also a surface-feeder. Clover, in division 3, takes much the same food as the root crops, but is a subsoil-feeder—that is, sends its roots deeply into the ground. The wheat in division 4 is also a subsoil-feeder, but like barley takes up much silica.

The next year the position of the crops is changed. Barley is grown on division 1, clover on division 2, wheat on 3, and so on: so that once every four years each part of the soil has each kind of plant growing on it, and the full rotation is thus shown :—

	1st Year	2nd Year	3rd Year	4th Year
1st Division	Root Crops	Barley	Clover	Wheat
2nd ,,	Barley	Clover	Wheat	Root crops
3rd ,,	Clover	Wheat	Root crops	Barley
4th ,,	Wheat	Root crops	Barley	Clover

At the same time various manures are employed to supply the place of the different materials removed from the soil.

3. The root is also, as we have seen, an **organ of excretion**; some of the sap, by osmosis, passes out into the soil, whilst the food enters the root. This is most important, as the sap is found to possess, as a rule, an acid reaction (that is, it turns vegetable blues, such as litmus, red), and hence it aids the root by dissolving some of the materials present in the soil. Many of these substances, which are very needful for the food of the plant, are insoluble in water, but the acid sap dissolves them readily.

This can be easily shown by means of an experiment. Take a piece of perfectly smooth marble, and cover it with sand to the depth of about a quarter of an inch; sow in this some seeds of mustard or cress, and place in a position favourable for germination. When the young plants have grown for a short time, clear the whole off, and it will be found that the rootlets will have eaten their way into the marble, dissolving the substance, and forming minute grooves where they had been.

This explains how it is that we sometimes see large trees with their roots sunk into the solid rock. They have sprung up in that position from seeds, and as the roots have grown the acid sap has gradually eaten a passage for them until they have attained their present firm condition. Added to this, the root exerts a mechanical force, splitting the rock in the direction of pre-existing grooves, and thus helping to form a passage for their growth. On the high road between Buxton and Longnor, at a village called Sterndale, several large trees are close to the road-side, growing through immense blocks of limestone, which blocks have been split by the expansive force of the tree.

4. The preceding functions belong more or less to all roots; there is, however, a fourth, which is only occasionally seen. In some cases the root acts as a **storehouse of food.**

Let us take the case of a biennial plant, such as a Turnip. During the first year there are no flowers, but plenty of leaves. Food materials are absorbed and converted by means of the leaves into starch and other substances, which are stored up in the root, which latter becomes swollen. The next year the plant flowers and fruits, and this reserve of food is used up during the process, so that by the end of the second year the root has become shrivelled and fibrous.

CHAPTER VI.

DEVELOPMENT OF THE PLUMULE—FORMATION, STRUCTURE, AND FUNCTIONS OF THE STEM.

WHILST the radicle grows downwards to form the root of the plant, the plumule is elevated above the soil, and produces the stem, bearing leaves and other appendages.

Popularly the **stem** is looked upon as differing from the root in growing above the ground, but botanically there is a wider difference. Underground portions of many plants, as the Onion and Potato, which are generally called roots, are in reality stems.

The characters of stems as distinguished from roots are as follows:—

1. Their **growing points** are not covered with a root-cap, but are **surrounded by young leaves** (buds).

2. They have developed upon them **appendages**, variously modified, but which differ in structure from the stems themselves; whilst roots simply branch, the branches being repetitions of the structure of the original root.

3. Whilst, as we have seen, the branches of the root have their origin in the deep-seated layers of the pericambium (endogenous growth), the **branches** and appendages of stems take their rise from more superficial layers (**exogenous growth**).

If we make a transverse section across the young stem during the first year of its growth, we find that there is a great difference in the appearance it presents in the two great groups of Dicotyledons and Monocotyledons.

Fig. 63 shows the section of a portion of a young dicotyledonous stem. On the exterior there is an **epidermis** of flattened cells.

At first this is like the epidermis of the root, consisting of a number of similar cells, always completely in contact; but after a while some of these become separated from one another,

leaving an opening or **stoma** (plural, **stomata**) between them (Fig. 64).

These stomata are always surrounded by two or four cells, which are generally smaller than the epidermal cells, are crescent-shaped, and contain chlorophyll. These are known as **stomatal** or **guard cells.**

More towards the interior of the stem there are developed some **bundles of cells** (Fig. 63). At first these bundles consist

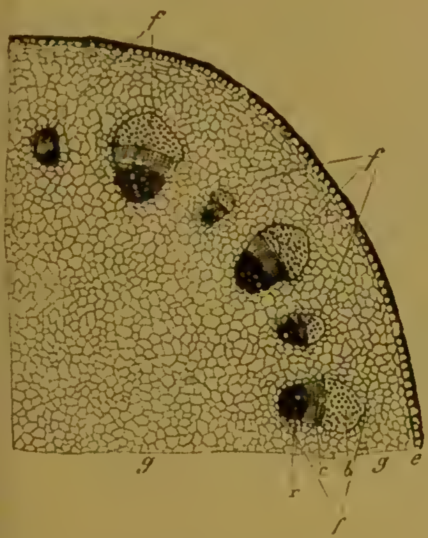

FIG 63.—Transverse section of petiole of *Helleborus*, showing the three systems of tissues: *e*, epidermal; *f*, fibro-vascular; *x*, xylem; *c*, *b*, phloëm—*c*, soft bast; *b*, bast-fibres; *g*, ground or fundamental tissue. (After Prantl.)

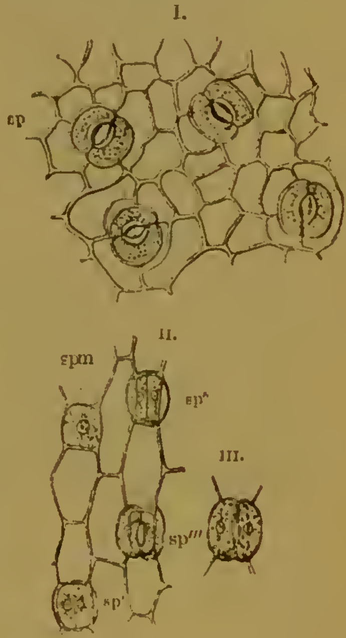

FIG. 64.—I. Horizontal section through the epidermis of the under side of the leaf of *Euonymus japonicus* looked at from below: *sp*, stomata. II. Course of development of the stoma of *Arthropodium cirrhatum*: *spm*, mother cell ready for division; *sp'*, *sp''*, *sp'''*, successive stages of division. III. Mature stoma.

of meristem tissue, known as **procambium**, forming a string of similar and growing cells. Very soon, however, the greater part of this passes into the form of permanent tissue, which is separated into an outer or **phloëm** and an inner or **xylem** portion, leaving a band of meristem (**cambium**) between them (Fig. 65).

The bundles, which now consist of fibres and vessels, with a few parenchymatous cells, are spoken of as **fibro-vascular**

bundles. In many cases the fibres and vessels become very much hardened by the thickening of the secondary deposit, and the fibro-vascular bundles can then be easily separated from the surrounding portions of the stem. In other cases there is very little hardening in the bundles, and they cannot be thus separated.

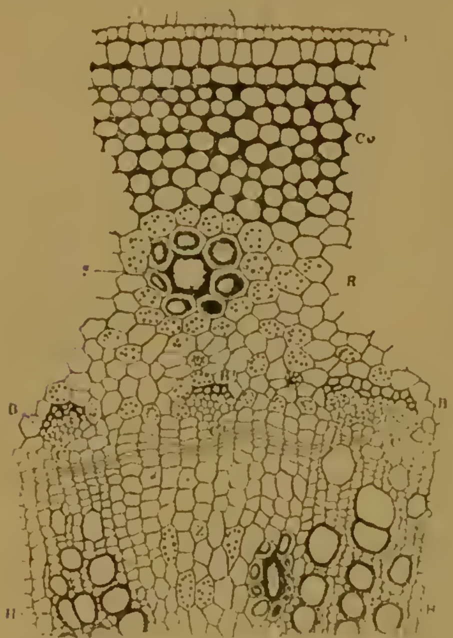

FIG. 65. Transverse section through a young internode of *Bœhmeria argentea* : E, epidermis ; CO, outer cortex (collenchyma) ; R, inner cortex ; S, intercellular space ; C, cambium of the vascular bundle ; C′, cambium of the thickening ring ; B, bast portion ; H, xylem portion of the vascular bundle ; B′, the bast formed from the intermediate cambium ; Z, medullary ray.

The rest of the stem in its young state is made up of parenchymatous cells, forming what is known as **fundamental** or **ground tissue**, which is divided into three parts—a portion in the centre of the stem, the pith or **medulla** ; the cells immediately beneath the epidermis forming the **cortex**—some of the cells towards the periphery have thickened walls, consisting of cellulose, living contents and chloroplasts, forming tissue known as **collenchyma** (Fig. 65); the innermost layer of the cortex contains starch granules, as can be seen on staining a section with iodine, and forms a layer, the **endodermis**, or **bundle sheath**, surrounding the fibro-vascular bundles ; and lastly, masses of cells which separate the fibro-vascular bundles and unite these two portions, the **medullary rays.**

The next change is in the cells which lie between the fibro-vascular bundles and the epidermis. Here are produced flattened cells filled with air, possessing flexible and elastic walls forming a close tissue without interspaces. These are **cork cells,** or **periderm.** They are rarely (as in the Willow) developed from the epidermis itself; sometimes (as in the Poplar) from the cells immediately beneath it, more often from the more deeply lying cells.

On the inner side there is developed a ring of meristem,

known as **phellogen**, or cork cambium; whilst within this there is a layer of cells containing chlorophyll, the **phelloderma** or green layer. The cork tissue is impervious to water, hence, after it has been formed, the epidermis and all the cells between it and the cork die, and usually peel off, being replaced as a protective tissue by the cork. The term **bark**

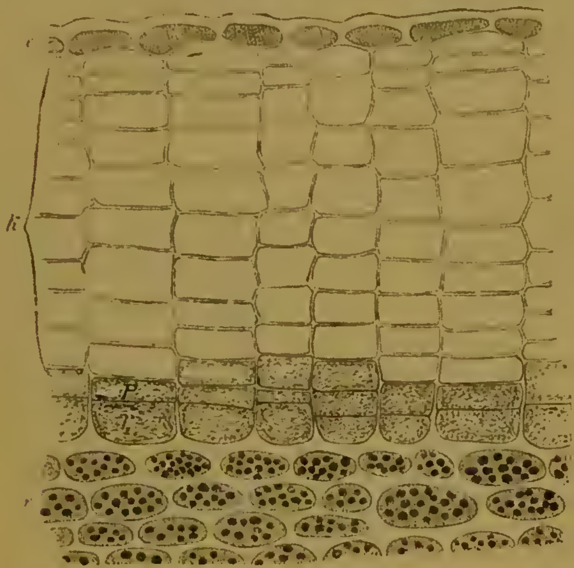

FIG. 66.—Transverse section of one-year-old stem of *Ailanthus glandulosus*: *e*, epidermis withered; *k*, cork cells, formed by the inner cells with protoplasm, the cork cambium or phellogen; *r*, inner green cells, the phelloderma. (After Prantl.)

may be used to denote all the dead tissue outside the living cork cambium cells.

The dicotyledonous stem now consists of the following parts:—

1. A ring of **epidermis** and cells with it becoming dried and dead.

2. A ring of **cork tissue**, the outer bark, with the cork cambium within.

3. A ring of **phelloderma**, the middle bark.

4. A ring of **cortex** or ground tissue.

5. A ring of **phloëm**, interrupted by the passage of the medullary rays, and forming the bast, liber, or inner bark.

6. A ring of **cambium**, also interrupted by the passage of the medullary rays.

7. A ring of **xylem**, or wood similarly interrupted.

7. **A central pith,** or medulla.

8. **The medullary rays,** uniting the pith with the middle bark. (See Fig. 65.)

In the monocotyledonous stem (Fig. 67) there is quite a different arrangement. On the exterior there is no differentiated bark; within, no separation into pith and medullary rays; but a number of bundles of procambium scattered amongst the general ground or fundamental tissue. These bundles differ in their development as well as in their arrangement from those of the dicotyledonous stem. Instead of leaving a layer of vitally active cambium, they are entirely converted into xylem and phloem. In many monocotyledons, as in Butcher's Broom and Asparagus, there is a distinct endodermis surrounding the bundles; in other cases, however, it cannot be distinguished from the general cells of the ground tissue.

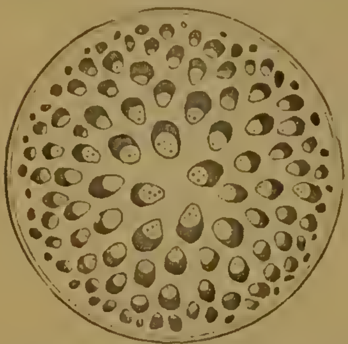

FIG. 67.—Diagrammatic representation of the distribution of the fibro-vascular bundles in the transverse section of a Palm stem.

The ground tissue, and, to a less extent, most of the other tissues also, show spaces *between* the cells that are filled with air These **intercellular spaces** are found in all dicotyledons and monocotyledons.

Dicotyledonous bundles which contain cambium are spoken of as **open,** whilst those bundles which are destitute of this formative tissue, as those of **monocotyledons,** are known as **closed.**

We must now note a little more fully the structure and functions of the various parts of the dicotyledonous stem.

1. The **medulla,** or **pith,** consists entirely of parenchmatous cells, generally dodecahedral in shape, and it forms a cylindrical axis at or towards the centre of the stem. In the earlier stages the cells usually contain a little chlorophyll, and are filled with nutrient substances; later on they become dry and colourless, and filled with air, and no longer serve any purpose in the life of the plant, so that the stem may be hollowed, all the pith having disappeared, and yet the plant may be living vigorously.

The amount of pith varies much in different plants. In hard-wooded plants, as the Ebony, it is very small; whilst in soft-wooded plants, as the Elder, it is much larger. Again, we often find in many rapidly growing herbaceous plants, as

the Hemlock, the pith, not being able to keep up in growth with the other parts, has left the stem hollow, with a rugged attachment of pith at the sides; whilst in the Walnut and Jessamine it has become broken up into thin discs (*discoid* pith).

2. Surrounding the pith there is a layer of spiral vessels (the **medullary sheath**), which is in reality the commencement of the wood or xylem. The function of these vessels, as indeed of all true vessels, is to serve as water-carriers. Like the wood, cambium, and liber, the medullary sheath is pierced by the medullary rays.

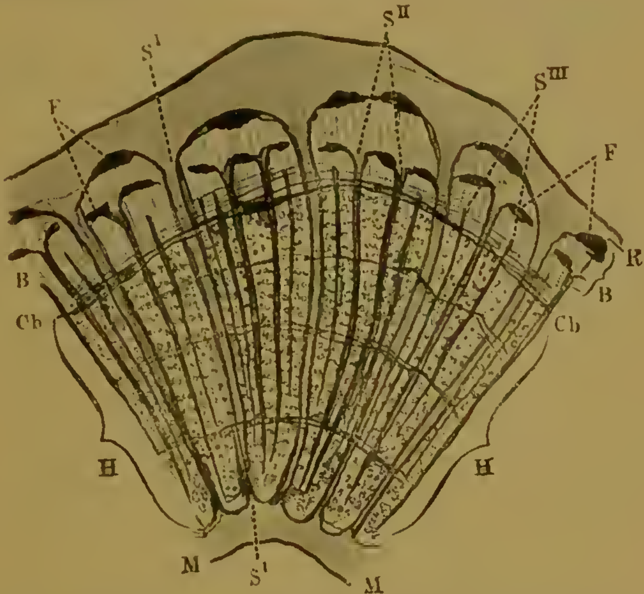

FIG. 68.—Portion of the transverse section through a shoot of Ivy four years old: R, cortex; B, bast bundles; H, wood, in which the four annual rings are distinctly visible; M, pith; S′, medullary rays; F, bast fibres; *cb*, cambium; S″, primary, S‴, secondary bundles.

3. Outside the medullary sheath comes the **xylem**, or wood, arranged in the form of concentric rings. These rings are formed as follows. During the first year the cambium cells by their division have caused the wood and liber to increase in thickness. During the winter the cambium remains dormant, but as soon as spring returns the cells once more become vitally active, and form a fresh ring of wood on its interior *outside* the old xylem, and a fresh ring of liber on its exterior *inside* the old phloëm. Thus year by year fresh rings of wood and liber are formed (Fig. 68), the oldest wood being towards the centre of the tree, whilst the oldest bark is towards the exterior.

As fresh rings of wood are as a rule formed every year, the age of a tree can generally be approximately ascertained by counting the number of the rings. The annual rings of various trees differ very much in the extent of their thickness, much depending not only on the nature of the plant itself, but also on its age and the atmospheric conditions of the climate. Also in the same plant the rings are not of equal thickness all round, so that the pith, instead of being geometrically in the centre of the tree, is generally more or less eccentric.

When these wood rings are fully developed they consist of three elements, viz. :—

a. Wood fibres or wood prosenchyma.

b. Vessels, either spiral, annular, pitted, or otherwise.

c. A variable quantity of wood parenchyma.

These three elements are variously arranged, and any one of them may be absent. Generally there is plenty of secondary deposit on the cell-walls, so that the cells have become hard. The inner wood is, as we have seen, the oldest, and is often coloured by the secondary deposit having colouring manner. This is especially well seen in such wood as Ebony, Mahogany, Rosewood, etc. In other cases, as in the Poplar and Willow, the old wood is nearly as colourless as that of the exterior. This inner wood is known as the **duramen** or heart-wood.

The xylem on the exterior, which is younger, is permeated with sap, and is known as the **alburnum**, or sap-wood.

The heart-wood is principally useful in supporting the plant, so that it may be absent as well as the pith without interfering with the vital activities of the tree.

4. Outside the xylem there is the interrupted ring of **cambium**, consisting of prosenchymatous cells dormant during the winter, and in full activity on the return of spring. During the first year cambium is commonly formed between the fibro-vascular bundles **(interfascicular cambium)**, thus making the cambium ring complete (see Figs. 65 and 69, B). By means of this interfascicular cambium, not only are the medullary rays lengthened as the stem increases in thickness, but also fresh phloëm and xylem are produced between the original bundles.

5. Outside the cambium there is the interrupted ring of **phloëm**, liber, or inner bark. Like the wood, this consists of three elements, viz. :—

a. The bast vessels, or sieve-tubes (Fig. 36).

b. Bast fibres (Fig. 38).

c. Bast parenchyma, or soft bast.

Some of these cells are small, and appear to be cut off from

he sieve-tubes—they are known as **companion cells** ; others are arger, and are called **cambiform cells.**

The separate annual layers of the liber cannot, as a rule, be so readily distinguished as those of the wood, they being

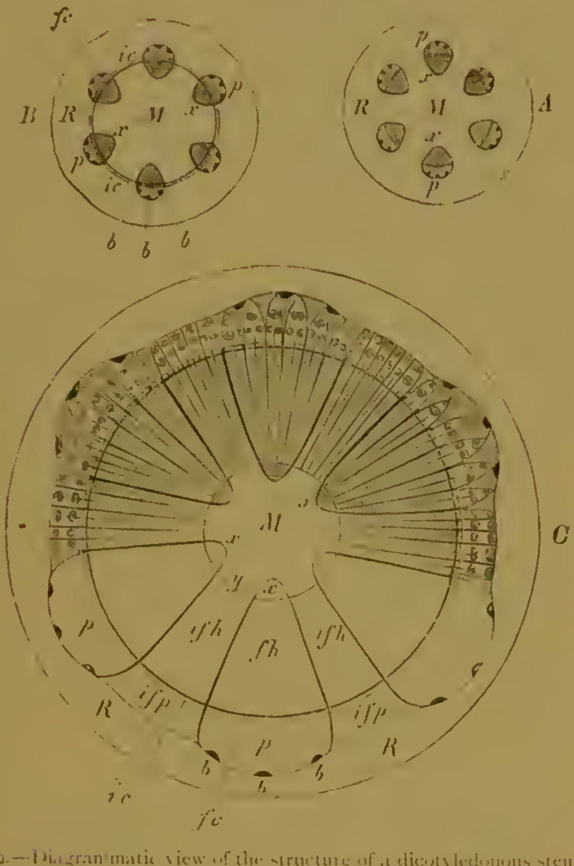

FIG. 60.—Diagrammatic view of the structure of a dicotyledonous stem with circumferential growth as seen in transverse section. *A*—M, R, ground tissue forming pith (M) and cortex (R), the external ring representing the epidermis. Six fibro-vascular bundles separate—*x* the xylem, and *p* the phloëm of each bundle. *B*—older stem: the bundles now united by cambium ring of fascicular (*fc*) and interfascicular (*ic*) cambium; *b*, *b*, the primary bast fibres of the phloëm. *C*—still older stem. By the activity of the cambium new wood and bast have been formed. *fh*, wood formed by fascicular cambium; *ifh*, wood formed by interfascicular cambium; *ifp*, interfascicular phloëm; *x*, *y*, medullary sheath. The shaded upper part shows medullary rays. (After Sachs.)

much thinner and compressed together by the growth in thickness of the tree. In some cases, however, the liber can be separated into thin plate-like layers.

A good example of this is to be seen in the Lace bark tree (*Lagetta lintearia*) of Jamaica, where the inner bark separates

into thin sheets having the appearance of lace, the holes in it being the perforations for the passage of the medullary rays.

The fibres of the bast act as sap-circulators, bringing down the elaborated sap from the leaves.

6. The *green layer*, or **phelloderm**, consists of chlorophyll containing cells, often intermixed with laticiferous vessels.

7. The *outer* or **cork layer** with its formative phellogen immediately beneath it. These two last layers form a protective coat to the exterior of the stem. After a short time the cells generally become dead, and very often peel off under the expanding influence of the growth of the stem.

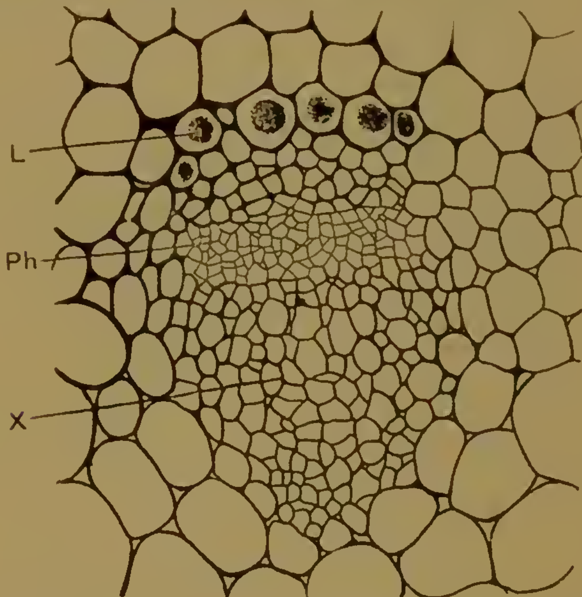

FIG. 68.—Part of the transverse section of a stem of Sowthistle (*Sonchus asper*), showing a vascular bundle and laticiferous vessels (L), together with Phloem (Ph) and Xylem (X).

This, as is seen in the Elm or Cork Oak, gives a rugged appearance to the bark. In other cases, as in the Beech, owing to its capability of distension, the bark presents a smooth appearance.

In very many cases there appears small scars upon the bark, known as **lenticels**; a section shows that each lenticel contains cork cells, loosely arranged so that gases and vapours can pass through. These lenticels communicate with the intercellular spaces of the entire plant. They are usually formed beneath the stomata of the epidermis, and replace them in the Cork. In the winter they are closed by the formation of cork tissue, which is ruptured again next spring.

8. The **medullary rays** uniting the pith with the middle bark, and separating the fibro-vascular bundles. They are

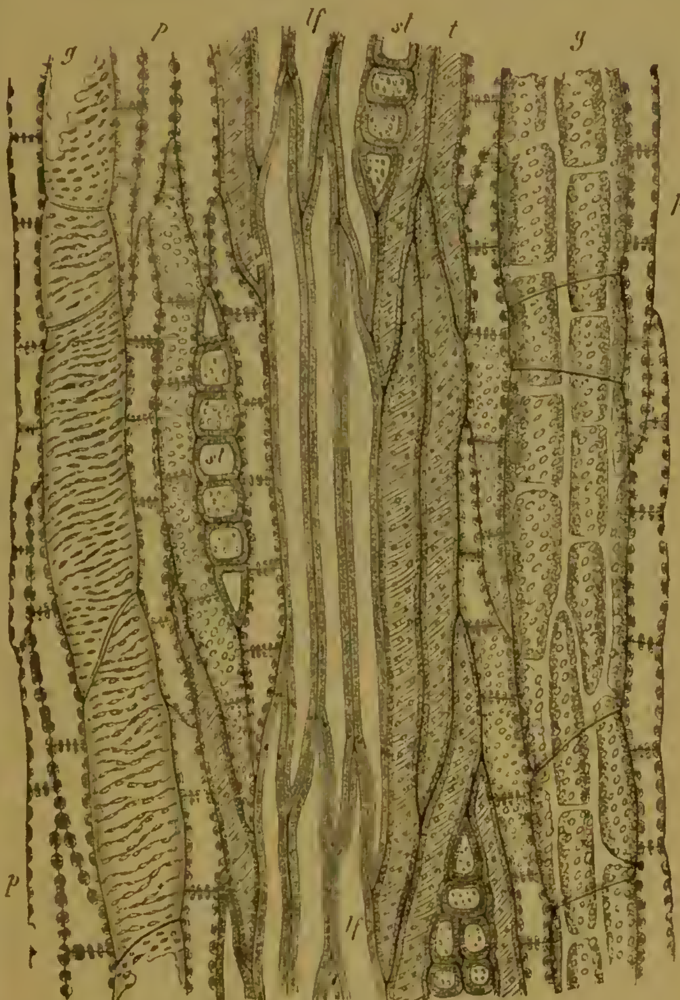

FIG. 71.—Longitudinal tangential section of stem of *Ailanthus*, showing secondary xylem of fibro-vascular bundles; *g, g*, wood vessels; *p*, wood parenchyma; *t, lf*, wood prosenchyma, of two varieties; *t*, tracheïdes, with pitted and spiral markings, and *lf*, libriform or bast-like wood fibres; *st*, medullary rays cut across. (After Sachs.)

generally made up of flattened, six-sided cells, arranged like bricks in a wall.

The rays are rarely continuous from the top to the bottom of the stem being separated by the fibro-vascular bundles (*st*, Fig. 71).

The medullary rays form what is known as the "silver

grain" of the cabinet-makers. The use of the rays is to distribute the elaborated sap from the liber through the other parts of the stem, and in a general way to serve as a means of communication between the different stem-tissues in the radial direction.

In most cases the fibro-vascular bundles are continuous with those which form the veins of the leaves, and are known as "**common bundles,**" *i.e.* common to leaf and stem. At the nodes (the point of attachment of the leaf to the stem) these bundles enter the stem and run down parallel to one another, usually through two or three internodes. That part of the common bundles which is in the stem is often spoken of as the **leaf-trace bundles.** On examining a stem from which the leaves have fallen, scars are often seen which mark the point of foliar attachment, and in these scars the bundles frequently appear as points. At the nodes the bundles branch and interlace in various ways, whilst they thin out the further they descend. In some few water plants, as the Hippuris or Mare's Tail, the Myriophyllum or Milfoil, and a few others, the fibro-vascular bundles run simply through the stem, or are **cauline,** the foliar originating later.

The direction of the fibro-vascular bundles can be readily traced by making a longitudinal section of a young stem, taking care to cut through at least two nodes, and then soaking it for five or ten minutes in a solution of aniline sulphate acidulated with a few drops of sulphuric acid: the lignin of the bundles will be stained yellow, and hence their position can be noted.

STRUCTURE AND FUNCTIONS OF THE PARTS OF A MONOCOTYLEDONOUS STEM.

Even in their external form monocotyledonous stems present a different appearance from the dicotyledonous stems described. In this country we possess no indigenous monocotyledonous tree (the Butcher's Broom is the only indigenous shrub), but the exotic Palms (Fig. 72), instead of having tapering stems like our forest trees, possess them of much the same diameter from top to bottom.

Within there is no separation into pith or bark. On the exterior there is an epidermis and a cortex, or false rind, made up of the ends of the fibro-vascular bundles. These bundles enter the stem from the bases of the leaves, being continuous with the bundles present in them. At first they are narrow. They grow inwards, and then pass down the interior of the

stem, gradually increasing in diameter. At length, having attained their largest size, they began to curve outward again, thinning as they do till they end at the exterior (Fig. 73).

The bundles are closed, containing no cambium, hence

Fig. 72.—*Livistona australis*, a Fan Palm.

after their formation they cannot increase in size. A section across the stem will show the younger bundles within and the

older ones without. Such an arrangement is due to the peculiar course followed by the individual bundles in the stem.

In annual and herbaceous monocotyledons the ground tissue is soft and delicate; but in trees, as Palms, it is much hardened by secondary deposit, forming *woody parenchyma.*

It follows from this structure that it is impossible for such

Fig. 73.—Course of the vascular bundles of *Iris* in longitudinal section (diagrammatic).

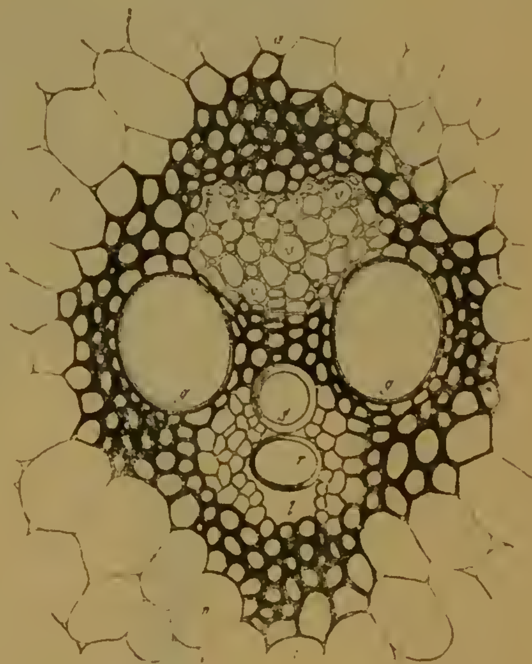

Fig. 74.—Transverse section of fibro-vascular bundle of *Zea Mais*: *p*, thin walled parenchyma of ground tissue of, *a*, outer and, *i*, inner part of stem, with thick-walled prosenchymatous ground tissue internal to it; *g*, *g* large pitted vessels; *s*, spiral vessel; *r*, isolated ring of annular vessel; *l*, air cavity; *v*, *v*, cambiform tissue or soft bast. (After Sachs.)

a stem to increase in thickness after the outer rind has become thoroughly hardened.

In some Monocotyledons of the Lily tribe, as the Aloe and Dragon-tree (Fig. 75), there is a provision for the formation of new bundles, but in a different manner from that which takes place in Dicotyledons.

A layer of meristem is formed in the outer part of the ground tissue, by means of which the stem is increased in

the thickness, and in which new fibro-vascular bundles are formed.

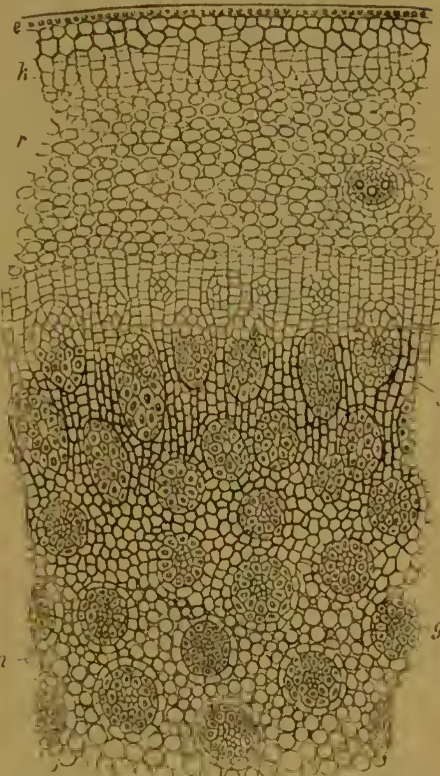

FIG. 75.—Transverse section of stem of *Dracæna*, near apex: *e*, epidermis; *k*, cork; *r*, cortical portion of ground tissue; *b*, fibro-vascular bundle to leaf; *m*, ground tissue of centre of stem; *g*, fibro-vascular bundles; *x*, meristem zone, developing new fibro-vascular bundles (*g'*) and new ground tissue (*st*). (After Sachs.)

EXTERNAL FORMS OF STEMS.

A section of the stems usually shows it to be more or less cylindrical in shape; at other times it is angular, being either triangular, square, five-ribbed, etc. (Fig. 76).

When the stem is herbaceous, and dies down annually, it is called a **caulis**; when woody and perennial, a **trunk**; and when jointed, as in Grasses, a **culm**.

Generally stems are able to support themselves in an upright position, and are **erect**; if they trail on the ground they are **prostrate**; if, whilst thus reclining, they rise towards their extremities, they are **decumbent**; or if they gradually rise from near the base, **ascending**.

Some stems are **climbing**, attaching themselves to some object of support either by *rootlets* (as in the Ivy), or by *tendrils* (as in the Passion Flower and Sweet Pea). At other times they are **twining** around the object of support (as in the Bindweed and Hop, Fig. 77).

FIG. 76.—I. Section of triangular stem. II. Section of square stem. III. Section of five-ribbed stem.

There are certain terms which are applied to various forms

of stems, some of which describe the aërial or above ground, and others the subterranean stems.

1. **Aërial Stems.**

a. **The Runner.**—This is well seen in the Strawberry, where

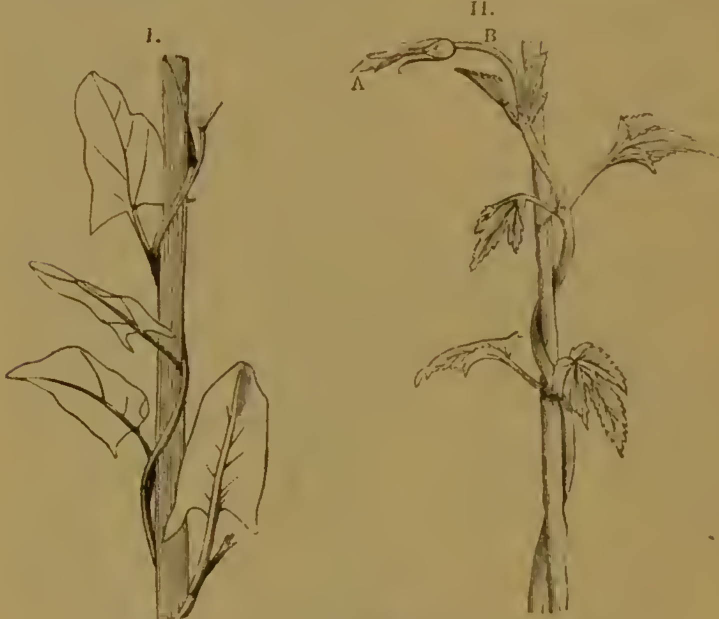

FIG. 77.—I. Stem of *Convolvulus arvensis* twining to the left. II. Stem of Hop twining to the right.

a branch springing from a plant creeps along the ground (often with a modified leaf or scale upon it), and ultimately

FIG. 78.—Runner of Strawberry (*Fragaria vesca*).

FIG. 79.—The offset of the Houseleek (*Sempervivum*).

strikes in the soil, producing leaves and roots, and forming a new plant (Fig. 78).

b. **The offset,** seen in the Houseleek, much resembling the runner, but shorter and thicker (Fig. 79).

c. The **stolon**, as in the Gooseberry and Currant, is really a branch given off above the ground striking into the earth and giving off roots and leaves, forming a fresh plant. This is often imitated by gardeners in the process of layering, when they bend down a branch into the soil, thus causing it to take root and produce a fresh plant.

d. **The Sucker.** — This differs from the last in being a branch springing from beneath the soil, and after proceeding for a short time in a horizontal direction, giving off roots as it does so, turns up and grows out of the ground, forming a new plant. The Rose and Mint are examples.

FIG. 80.—Stolon.

2. **Subterranean Stems.**

e. The **rhizome** or **rootstock** is a thickened stem creeping either at the surface of the soil or just below it, giving off leaves from the upper surface, and roots from the lower. As the leaves fall off year by year, they leave scars marking where they had been. These, together with other subterranean stems, are popularly termed roots, but are distinguished from true roots in the manner already indicated. Examples are to be found in the Iris, Sweet Flag, Ginger, Solomon's Seal, etc.

FIG. 81.—Sucker.

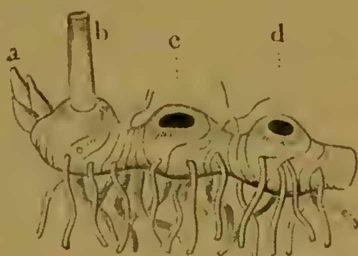

FIG. 82. Rhizome of Solomon's Seal (*Convallaria Polygonatum*): *a*, terminal bud from which is developed the next year's stem; *b*, this year's stem; *c*, *d*, scars of the stems of previous years.

f. The **soboles** or **creeping stem** is thinner than the rhizome, but otherwise resembles it. It is met with in the Sand Sedge (Fig. 83) and Couch Grass. In the former plant it is often of great use in binding together the loose sands of the sea shore, whilst in the latter it is a pest to the farmer.

g. The **tuber** is an underground stem or branch, which is

Fig. 83.—Creeping rhizome of *Carex*.

much swollen by the deposition of a large quantity of starch and other food materials. It possesses leaves which are more or less modified. In the Potato (which is a good example of the tuber) the eyes are the modified leaf buds. It is a well-known fact that if the aerial branches of a Potato plant are earthed, their growth will be arrested and tubers will be formed.

Other examples of tubers are to be seen in the Jerusalem Artichoke and in the Pig Nut.

The two following modifications of stem are only to be met with amongst monocotyledonous plants.

h. The **bulb** consists of a more or less flattened disc-like stem, giving off roots below, and scale-like leaves, together with stem and flowers, above.

The scale-like leaves have the power of developing in their axils smaller bulbs or buds known as *cloves* or *bulbils* (*a*, Fig. 86). There are two forms of bulb. When the inner scales

Fig. 84.—A six-weeks-old Potato plant, developed from the seed, the upper branches, *a*, *b*, being cut off: *d*, cotyledons; in the axils of the cotyledons are developed the underground branches, *e*, *e*, which penetrate into the ground and form tubers, *f*, *g*, at their apex or in the axils of small leaves. The tubers are found only on the branches which are produced in the axils of the cotyledons, never on the true roots *h*.

Fig. 85.—Single tuber of the Pig Nut (*Carum bulbocastanum*).

Fig. 86.—Scaly (squamose) bulb of the Onion: *b*, plate or disc; *a*, bulbils.

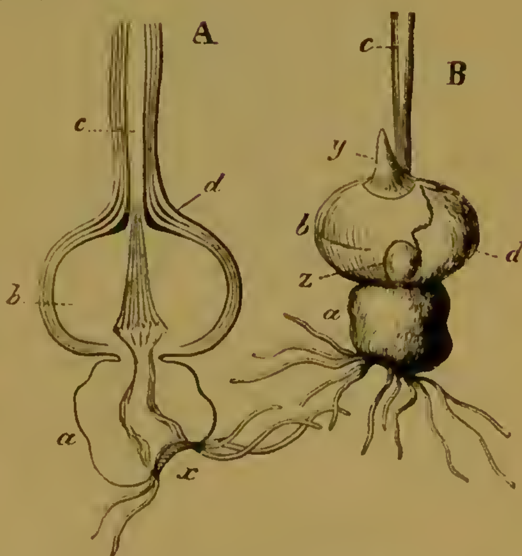

Fig. 87.—Corm of *Gladiolus segetum*. A, longitudinal section: *a*, last year's, *b*, this year's bulb; *c*, scrape; *d*, scales; *x*, roots; B, after removal of the enveloping scales: *y*, bud, which will develop into next year's corm; *z*, bulbil.

are fleshy, and are covered by thin membranous ones, the bulb is said to be *tunicated*, as in the Onion. If there be no outer tunic, as in the Lily, the bulb is said to be *scaly* or *naked*.

i. The **corm** differs from the bulb in that the fleshy tissue belongs to the stem, instead of to the scaly leaves or leaf-bases. The leaves of the crocus are all either membranous scale-leaves or ordinary foliage leaves.

CHAPTER VII.

BUDS AND RAMIFICATION.

BRANCHES of the stem first make their appearance as **buds.** These as a rule do not appear indiscriminately but at certain

FIG. 88.—*a*, terminal bud: *b*, axillary bud, the leaf in the axil of which it was produced having been removed.

FIG. 89.—Diagram of a longitudinal section of the apex of the stem of a dicotyledonous plant; *m*, pith; *f*, fibro-vascular bundles, both developed from the pleurome (*pl*), the bundles sending branches to the leaves; *r*, corticle tissue; *e*, epidermis; *b*, *b*, young leaves, two showing their origin from protomeristem (*p*); *kn*, axillary bud. (After Prantl.)

definite parts of the plant, viz. at the extremities of the stem and branches, when they are called **terminal buds**; and on the sides of the branches, when they are called **lateral buds.** The most frequent position of the lateral buds is in the axil of the

leaves, that is to say, in the angle formed between the leaf and the stem, when they are spoken of as **axillary buds.** In some cases, however, a lateral bud may appear either above the axillary bud, as in the Walnut; or on either side of it, as in the Maple. They are then called **accessory buds.**

If they grow from any other part of the plant they are said to be **adventitious.**

At first the bud consists entirely of parenchymatous tissue connected with the parenchyma of the stem. There is a central conical mass around which, after a while, vessels and wood cells are developed; outside these, parenchymatous tissue which forms bark, and which is covered with little scales of parenchyma variously overlapping one another, forming the rudimentary leaves.

FIG. 90.—Branch spines of the Sloe (*Prunus spinosa*).

FIG. 91.—Prickles of the Rose.

The portions of the young stem to which these leaves are attached are known as **nodes**, whilst the stem between the nodes forms the **internodes.**

If the bud is developed during the same season in which it has been formed, it possesses this simple structure. If, however, it remains undeveloped until the following season, it forms a **winter bud**, or **resting bud**; in this case it is protected by scales, which sometimes, as in the Horse Chestnut and Poplar, possess resinous secretions, and at other times, as in Willows, are covered with hairs.

Though at first sight these bud scales are very different in

their appearance from the ordinary foliage leaves, yet examination shows that they are really of foliar origin, and they are often spoken of as **cataphyllary leaves.**

If, for instance, Lilac buds are carefully examined, there is found to be every gradation from the outer scales to the inner true leaves.

In the Lilac and the Privet the outer scales appear to represent the **leaf blade**; in the Horse Chestnut, Ash, and Maple it is the enlarged base of the **leaf stalk**; in the Beech, Oak, Alder, Magnolia, and Tulip tree, the scales are the **leaf stipules.**

The commencement of the development of the bud is by the growth of the internodes, by which the young leaves become gradually separated from one another and the branch is formed.

Fig. 92.—Stem tendrils of the Grape-vine: v', in the normal state; v, bearing a bunch of grapes.

If all the normal buds of the plant were developed, the branching would follow regularly the arrangement of the leaves.

This uniformity is often interfered with: 1st, by the non-development of buds; 2nd, by the formation of adventitious buds.

Sometimes many of the buds remain entirely undeveloped. At other times, instead of being developed into leaf-bearing branches, they form subsidiary organs.

1. **Spines** are often modified branches. They are met with in the Sloe or Blackthorn. At times they are small and destitute of leaves; often they bear leaves, and under cultivation they become developed into leaf-bearing branches. Thus, whilst the Sloe is spiny, the cultivated Plum bears only leafy branches.

There is a great difference between spines (as in the Sloe and Locust-tree) and prickles (as in the Rose and Bramble). In the former case the spines are modified branches, and as such are connected with the internal parts of the stem; in the

latter case the prickles are simply outgrowths of the epidermis and sometimes of the subjacent layers, the cell-walls of which have become hardened by the deposition of secondary deposit.

2. **Tendrils.**—Sometimes the buds become developed as tendrils or cirrhi, as in the Grape Vine (Fig. 92), enabling the plant to hold on to the object of support.

Both spines and tendrils *may* be modifications of parts of leaves. The spines of the Barberry, and of some species of

Fig. 93.—Sweet Pea (*Lathyrus odoratus*).

Acacia (Fig. 129), and the tendrils of the Sweet Pea (Fig. 93), are examples.

We can tell, however, which they are by their position. If they are in the axils of leaves they are modified branches; if upon the stem and bearing buds in their axils, or forming part of the leaf, they are modified leaves.

In some cases adventitious buds are formed beneath the bark, and are not developed externally. In such cases they produce considerable variations in the figure and grain of the wood. Bird's-eye Maple is a very good example of this.

Buds are often capable of being removed from one plant and made to grow upon another of the same family. Upon

Fig. 94.—Grafting: *d*, the stock to which the graft is attached.

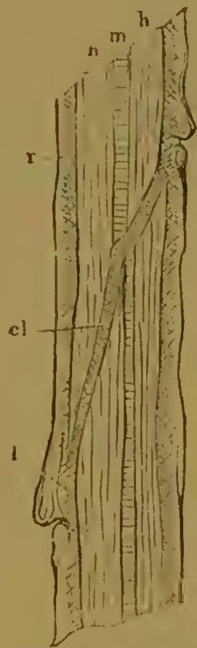

Fig. 95.—Diagrammatic representation of a longitudinal section through a graft: *cl*, the callus; *r*, bark; *m*, pith.

this fact depend the important operations of **grafting** and **budding**.

In grafting, a branch of a superior variety, possessing buds, is taken and implanted on a wild stock (Fig. 94). The formative cambium round the wound grows, forming a protective succulent cushion of tissue known as a **callus** (Fig. 95). The graft grows independently of the stock, receiving, however, its nourishment through it.

In budding, a bud, together with the surrounding bark, is removed from a superior variety, and a T shaped incision is made in the stock, beneath which the bark of the bud is inserted,

the whole being bound round to protect it from the action of the atmosphere (Fig. 96).

The bud grows in the same way as the graft.

FIG. 96.—The various elements in the process of budding.

The terms **vernation** and **præfoliation** are employed to express the way in which the young leaves are arranged in the bud. We have two things to notice, viz. 1st, the arrangement

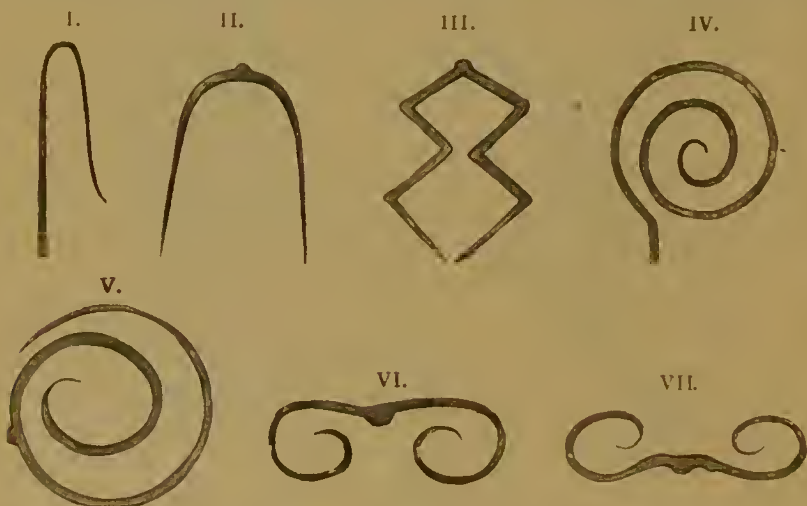

FIG. 97.—Various methods of leaf-folding in buds.

of each individual leaf; 2nd, the disposition of the several leaves in the bud.

1. *The Arrangement of the Separate Leaves.*—In the buds of the Firs they are **flat**. In other cases they are variously bent. If the apex approaches the base, as in the Tulip tree (Fig. 97, I.), it is **reclinate**. If the two edges meet together, leaving the midrib in the centre, as in the Oak and Magnolia (II.), it is

conduplicate. If each side be folded several times like a fan, as in the Lady's Mantle, Beech, Sycamore, and Vine (III.), it is **plicate.** When the apex of the leaf is rolled up towards the base, as in the Sundews, Ferns, and Cycads (IV.), it is **circinate.** When the leaf is rolled on itself, one margin being rolled towards the midrib, and the other margin rolled over it, as in the Apricot and Banana (V.), the folding is **convolute.** When the two margins are rolled towards the midrib on the under side of the leaf, as in the Dock and Rosemary (VI.), it is **revolute.** When the margins are rolled in the opposite way, that is, towards the upper surface of the leaf, as in the Violet and Water-Lily (VII.), it is **involute.**

(The diagrams of vernation are often at first hard to understand, unless we remember they represent *sections* cut across the leaves. A good plan is to cut out a large leaf in paper and to bend it in the forms described, after which an examination should be made of actual specimens.)

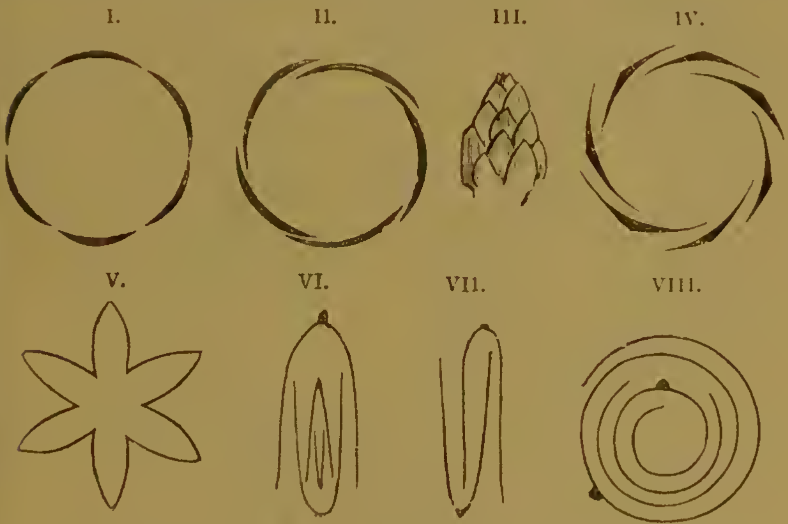

FIG. 98.—Forms of leaf-arrangement in bud.

2. *The Disposition of the Several Leaves in the Bud.*—In this case the leaves are either flat, or only slightly convex, or they are bent or rolled.

(*a*) *Leaves Flat or only Slightly Convex.*—The vernation is **valvate** (Fig. 98, I.) when the leaves are placed in the same level and simply touch one another by their edges. If they are placed at different levels and overlap one another like tiles of a roof, as in the Lilac (II. and III.), it is **imbricate.** When the

overlapping is carried further (as in Fig. IV.), it is said to be **spiral or twisted.**

(*b*) *The Separate Leaves Bent or Rolled.*—When, as in the Columbine, involute leaves touch by their edges without overlapping (v.), the vernation is **induplicate.** When, as in the Privet, conduplicate leaves are bent round one another (VI.), it is **equitant**; whilst when, as in the Sage, they are only half folded over one another (VII.) they are **obvolute** or **half equitant.**

When, as in the Apricot, a convolute leaf has another rolled outside it (VIII.), the vernation is **supervolute.**

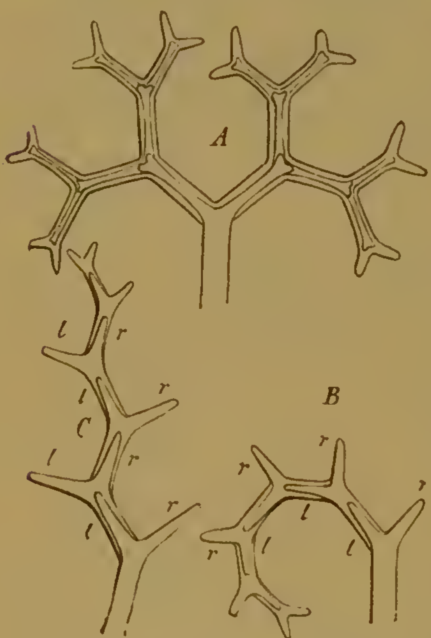

FIG. 99.—Diagrams of dichotomous branching. *A*, normal dichotomy, the forked branches equally developed, and becoming the podia of new dichotomies. *B*, Bostrychoid dichotomy, one fork-branch only becoming the podium of a new dichotomy: in this case the left (*l*). *C*, cicinnal dichotomy: one fork-branch, alternately left (*l*) and right (*r*), becoming the podium of a new dichotomy. *B* and *C* are sympodial arrangements. (After Sachs.)

In considering branching, whether of root, stem, or leaf, we must carefully distinguish the main **axis, foot,** or **podium,** and the branches. This, however, is not always easy.

1. In some cases the main axis ceases to grow when the branches are formed. Such branching is called **dichotomy** or **dichotomous branching.** The podium has at its extremity two growing points, each of which develops a branch. Sometimes both of these grow equally vigorously, each bifurcating in its turn, and a true **dichotomy** or **forked system** is produced (Fig. 99, A). Sometimes one branch becomes more strongly developed than the other; the system now becomes **sympodial,** the successive strong branches looking as though they were the continuous axis, and the weaker branches appearing to be lateral ones. If the stronger bifurcation is always on the same side, a **helicoid** or **bostrychoid dichotomy** is formed (Fig. 99, B). If the stronger bifurcation alternates, first to

the right and then to the left, we have a **scorpioid dichotomy** (Fig. 99, C).

2. If the axis is prolonged beyond the branch, a **monopodial** branching is produced. If the main axis continues to develop more strongly than the branches, the branching is said to be **racemose**; in other cases the main axis soon ceases to grow, and the shoots become strong; the branching is now said to be **cymose.**

There are two varieties of this :—

a. When two or more shoots arise near the apex of the podium and develop more strongly than the main axis, which soon ceases to grow. This is called **false dichotomy** (or if three branches, **trichotomy,** or if more than three, **polytomy**) (Fig. 100, C).

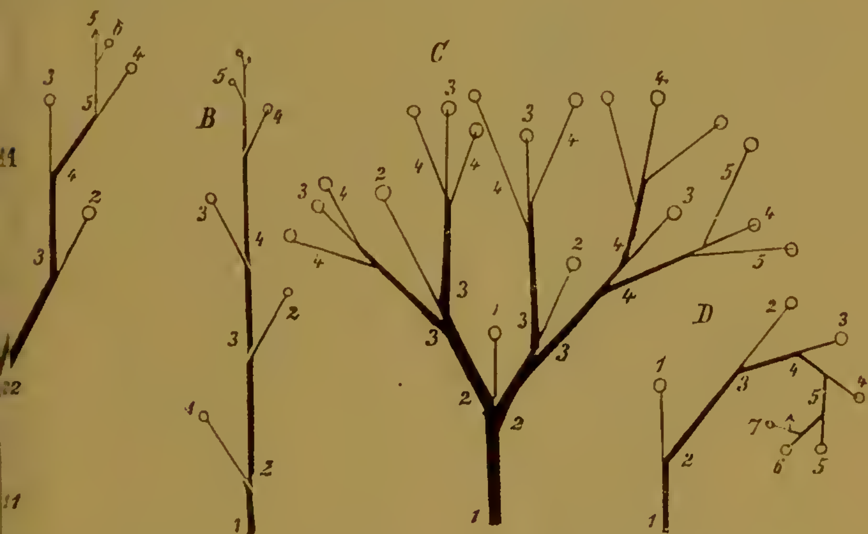

FIG. 100.—Diagrams of sympodial varieties of monopodial branching. *A* and *B*, cicinnal monopodia. *C*, dichasium, or false dichotomy. *D*, bostrychoid monopodium. The axes are numbered in succession from 1 to 7. (After Sachs.)

b. When only one shoot grows it forms a **pseud-axis** or **sympodium,** which may form a **scorpioid cyme** if the branches come off on opposite sides (Fig. 100, A, B), or a **helicoid cyme** if they all come off on the same side (Fig. 100, D).

True Dichotomous branching is very rare, being seldom met with in leafy shoots. It may be seen in the roots of Lycopods, in the shoots of Selaginella, and in the fronds of some ferns. Racemose branching is met with in the stem of conifers, also in the compound leaves of umbellifers and in the roots of dicotyledons. A false dichotomy (**Dichasium**)

is seen in the inflorescence of chickweed and other plants of the order Caryophyllaceæ, also in the stem of Mistletoe. The sympodial axis is to be met with in the annual shoots of many of our forest trees, such as the Elm, Beech, and Hazel.

CHAPTER VIII.

STRUCTURE AND FUNCTIONS OF LEAVES.

WHEN a leaf is perfectly complete, it consists of three parts :—
1. The flat expanded portion which is popularly called the leaf. This is the **lamina, or blade.** 2. The stalk, which

FIG. 101.—Oval leaf of the Apple, with two free stipules.

FIG. 102.—Sessile leaves of Shepherd's Purse (*Capsella bursa-pastoris*).

attaches this to the stem, the **petiole** or **leaf-stalk.** 3. The little leaf-like projections at the point of union between the petiole and the stem, the **stipules.**

In very many cases, however, there are only one or two of these parts present. If the petiole be absent, the leaf is said to be **sessile**; if the stipules, **exstipulate**.

FIG. 103.—Leaf of *Acacia melanoxylon*, showing phyllodes *a*, *b*.

The Wallflower and Shepherd's Purse (Fig. 102) are examples of plants with leaves which consist of lamina only. In some of the leaves of the Australian Acacias (Fig. 103), we have only the petiole developed. It grows in a flattened leaf-like expansion known as a **phyllode** (Fig. 103, *a*, *b*).

FIG. 104.—*Lathyrus Aphaca*: *r*, tendril; *b*, flower; *f*, fruit; *n*, stipule.

In the *Lathyrus Aphaca* (Fig. 104) the stipules are the only parts which are developed in a leaf-like manner, the lamina and petiole being converted into a tendril.

In structure the leaf consists of parenchyma, which is

intimately connected with the outer parenchyma of the stem, and prosenchyma forming the veins, and which is in like manner connected with the xylem and phloëm.

In a vertical section through the leaf we find the following parts (Fig. 105) :—

1. A flattened **epidermis** coating the upper (*b*) and under (*c*) sides. As a rule, the under surface possesses a greater number of stomata than does the upper.

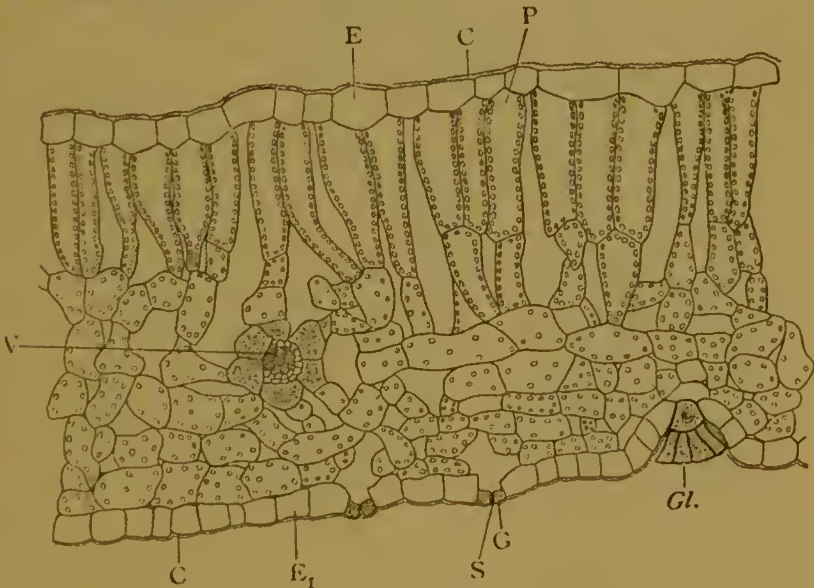

FIG 105.—Leaf of Privet. E epidermis of upper; E_1, of under surface; C, cuticle: P, palisade cells; V, vascular bundle enclosed in its sheath; S, stoma; G, guard cell; *Gl*, gland.

Professor Bentley gives the following table of the number of stomata found in a square inch of the two surfaces respectively of the various plants :—

	Upper Surface.	Under Surface.		Upper Surface.	Under Surface.
Mezereon . . .	None	4,000	Hydrangea . .	None	160,000
Paeony	,,	13,790	Mistletoe . .	200	200
Vine	,,	13,600	Tradescantia .	2,000	2,000
Olive	,,	57,600	Houseleek . .	10,710	6,000
Holly	,,	63,600	Garden Flag .	11,572	11,572
Laurustinus . .	,,	90,000	Aloe	25,000	20,000
Cherry Laurel .	,,	90,000	Yucca . . .	40,000	40,000
Lilac	,,	160,000	Clove Pink . .	38,500	38,500

Besides stomata, the epidermis is very frequently provided with hairs of various kinds.

These are simply prolongations of the epidermal cells,

sometimes unicellular (Fig. 106, I.), sometimes multicellular (Fig. 106, II.).

They vary much in their shape, sometimes being simple and at other times branched.

An interesting modification is seen in glandular hairs which contain various secretions; of these, stinging hairs, as are found in the stinging-nettle, are good examples. In this case there is a little bag at the base of the hollow hair, containing an acrid fluid, and surrounded by a number of elastic cells. The point of the hair is sharp, and is protected by a little cap. When the nettle is touched lightly, the cap is broken off, the point of the hair pierces the skin, and a drop of the stinging juice is forced into the blood. If the nettle be grasped firmly the sting is broken lower down, and hence there is no sharp point to pierce the skin, and the juice is simply poured out upon the exterior.

2. The surface of the epidermis is generally covered with a thin structureless layer, the **cuticle** (Fig. 105, *a* and *f*).

3. The parenchyma of the interior of the leaf consists of cells containing chlorophyll, forming the mesophyll.

There is a difference, however, in their arrangement in the different parts of the leaf. Towards the upper surface the cells are packed closely together (*c*, Fig. 105), whilst towards the under surface we find examples of stellate parenchyma, leaving air spaces between the cells (*d*, Fig. 105). This is the cause of the fact that in most leaves the under surface is lighter in colour than the upper, as there is less chlorophyll packed there.

The upper parts of the veins are in direct communication with the wood of the stem, whilst the lower parts are connected with the liber. At the edges of the leaves there is a passage between the upper and lower sides, so that the sap which passes up the wood flows out through the upper part of the veins, back through the under surface to the liber, and so down the stem.

There is a great difference in the **venation** or arrangement of the veins of the leaves in the two great groups of flowering plants.

In Dicotyledons the smaller veins run together, forming a complete network known as **reticulate venation** (Fig. 108).

In Monocotyledons, as a rule, there is no network formed between the principal veins, and the venation is said to be **parallel** (Fig. 109). (Some Monocotyledons, however, as the Aroids, have net-veined leaves.)

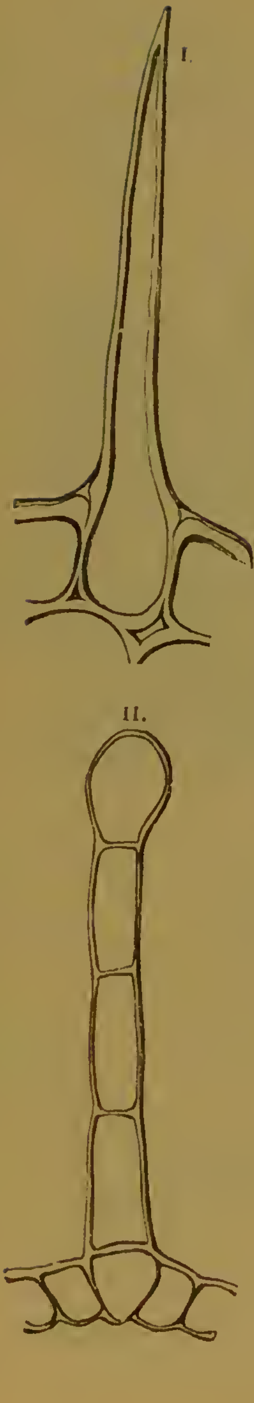

FIG. 106.—Simple hairs: I. Unicellular hair from the leaf of a Pelargonium. II. Multicellular hair from the stem of *Geranium pratense*.

FIG. 107.—Stinging hair of the nettle (*Urtica dioica*): the corroding fluid flows out of the hair when the vitreous knob-shaped apex is broken off.

There are varieties of both net-veined and parallel-veined leaves.

If we take the net-veined leaves, we find that there is either a single principal vein or midrib, as in the Guelder Rose (Fig.

Fig. 108.—Reticulately veined leaf of *Acer acutifolium.*

110), when the leaf is said to be **unicostate**, or there are several principal veins, as in the Maple (Fig. 108), when the leaf is **multicostate**.

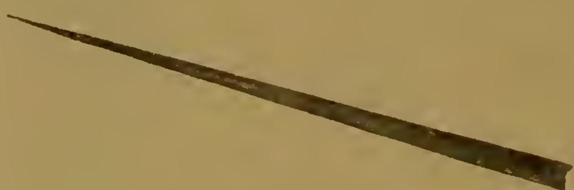

Fig. 109.—Parallel venation.

Again, amongst unicostate leaves in some cases the smaller veins curve towards the apex (Fig. 110), when we may term the

leaf **curved-veined**; in other cases they run more at right angle from the midrib to the margin (Fig. 111), when it is said to be **feather-veined.**

There are also two varieties of the multicostate leaves. In some cases, as in the Maple (Fig. 108), the diverging ribs never

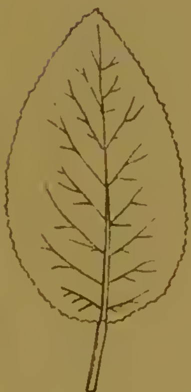

FIG. 110. — Dentate ovate leaf of the Guelder Rose, with unicostate venation (*Viburnum Opulus*).

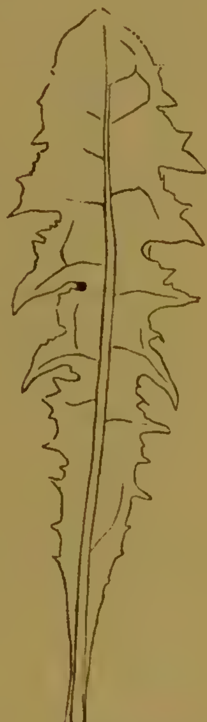

FIG. 111.—Runcinate leaf of the Dandelion, feather-veined.

FIG. 112. — Converging veined leaf of Cinnamon.

meet again. The venation of the leaf is then said to be **diverging** or **palmate.** In other cases, as in the Cinnamon (Fig. 112), they meet again at the apex, and the leaf is **converging veined.**

Of the parallel-veined leaves there are three varieties. When, as in the Grass (Fig. 109), the veins all run from the base to the apex, it is **straight veined.** When, as in the Banana, there is a central midrib, and the side veins run off to the margin, it is **transverse veined.** When, as in the Fan Palm (Fig. 72), there are several veins diverging from a common centre, it is **radiating veined.**

We may tabulate these forms of venation as follows:—

Reticulate-veined Leaves

Unicostate: Curved veined; Feather veined

Multicostate: Diverging veined; Converging veined

Parallel-veined Leaves

Straight veined; Transverse veined; Radiating veined

In describing leaves, besides the venation, we have to take into account the following points:—1. Composition; 2. Margin; 3. Incision; 4. Apex; 5. General outline.

FIG. 113.—Lyrate-crenate leaf of the White Mustard (*Brassica alba*).

1. **Composition.**—Leaves are either **simple or compound.** In simple leaves, as in the Apple (Fig. 101), there is only a single lamina; in compound leaves, as the Acacia (Fig. 103), the lamina is divided into a number of leaflets articulated to the common petiole.

2. **Margin.**—The condition of this depends upon the extent to which the parenchyma is developed between the veins. The margin may be **entire**, as in Grasses. More often there are indentations.

If the teeth thus formed are rounded (Fig. 113), the margin is **crenate.** If they are sharp, and point straight outwards (Fig. 110), it is **dentate.** If sharp and pointing towards the apex, like teeth of a saw (Fig. 101), **serrate.**

Sometimes the teeth are themselves divided, and we get **bicrenate, duplicodentate,** and **biserrate** margins.

If the margin of the leaf be covered with numerous hairs (Fig. 114), it is **ciliate.** If there be alternate concavities and convexities larger than crenated indentations, the margin is **sinuate** (Fig. 115).

When the teeth are very long and sharp, the margin is **spiny** (Fig. 116), and when the margin is very irregular, as in the Garden Endive and Curled Dock, it is **crisped.**

3. **Incision.**—We apply this term if the margin be more deeply indented than in the instances already described. If the indentations reach to midway between the margin and the midrib or petiole, we speak of them as **fissures**, and the portions of leaf between them as **lobes**, and the leaf is said to be *bi-*, *tri-*, etc., *-fid*. If the divisions go nearly to the base, or midrib, they are **partitions**, and the leaf is *bi-*, *tri-*, etc., *-partite*.

FIG. 114.—Ciliate leaf of the Beech.

FIG. 115. — Sinuate leaf of the Oak.

FIG. 116.—Spiny leaf of the Holly.

If quite down to the midrib or base **segments**, the leaf is *bi-*, *tri-*, etc., *-sected*. (For further remarks on this point, see under the head of Outline.)

4. **Apex.**—If the apex of the leaf be rounded (Fig. 115), it is **obtuse** or **blunt**. If it be sharp pointed (Fig. 110), it is **acute**, and if it gradually tapers to a point (Fig. 117), it is **acuminate**. When there is a rounded head, and a broad shallow notch in it, the apex is **retuse**, and when the notch is more triangular (Fig. 118), it is **emarginate**. When the apex is very abrupt as though cut off, it is said to be **truncate**.

When the apex is flattened and has a sharp point projecting (Fig. 119), it is called **mucronate**.

5. **General Outline.**—Various terms are employed for the description of the general outline.

If, as in the Grasses (Fig. 109), the two margins of the lamina are nearly parallel and the lamina itself is narrow, the leaf is **linear**.

If the leaf be sharp pointed and needle-like, as in many Conifers (Fig. 120), it is **acerose**. When the leaf is somewhat broad in the centre, and tapers towards the two extremities, as

in the Privet, it is **lanceolate** (Fig. 121). If more rounded at the extremities and broader in the centre, it is **oval**, or **elliptical**

FIG. 117. — Acuminate leaf of the Pellitory (*Parietaria*).

FIG. 118.—Leaf of *Oxalis micrantha*, with three obcordate leaflets.

FIG. 119.—Mucronate leaflet of the Lucerne.

FIG. 120.—*Pinus sylvestris*, the Scotch Fir, with acerose leaves.

FIG. 121.—Lanceolate leaf of the Privet.

(Fig. 101), and **oblong** when rather long. When, as in the Guelder Rose (Fig. 110), the leaf is broad and rounded at the base, tapering to a point at the apex, it is **ovate** or egg-shaped; and if the reverse, **obovate**, or inversely egg-shaped.

When the leaf is nearly round (Fig. 122) it is **orbicular** or **subrotund**. When, as in the case of the Lamium (Fig. 123), the leaf is somewhat hollowed out at the base, and pointed at the apex, so as to be roughly like a heart in a pack of playing cards, it is **cordate**, or heart-shaped, and when the reverse (Fig. 118), **obcordate**.

If the apex is rounded, instead of pointed, whilst the base

Fig. 122.—Orbicular leaf of *Malva rotundifolia.*

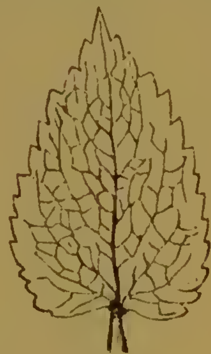

Fig. 123.—Cordate leaf of *Lamium.*

is hollowed, as in the Ground Ivy (Fig. 124), the outline is **reniform**, or kidney-shaped.

When the apex is rounded, and the leaf gradually tapers to the base (Fig. 125), it is **spathulate**, or spoon-shaped; or if it is more tapering, as in the leaflets of the Horse Chestnut (Fig. 126), the outline is said to be **cuneate**, or wedge-shaped.

When the leaf is somewhat of the form of an arrow-head (Fig. 127), it is called **sagittate**, or arrow-shaped; or if the barbs of the arrow point out more at a right angle to the blade, the leaf is **hastate**, or halbut-shaped (Fig. 128).

Fig. 124.—Reniform leaf of the Ground Ivy (*Nepeta Glechoma*).

Fig. 125.—Spathulate leaf of the Ox-eyed Daisy (*Chrysanthemum leucanthemum*).

There are also several terms which are applied to the outlines of compound and much-divided leaves. Thus, if a

compound leaf has two leaflets it is **binate**; if three, **ternate** (Fig. 118). A **quadrifoliate** leaf has four, a **quinate** five, a **septenate** seven, and a **multifoliate** leaf more than seven leaflets springing from a common point. When the leaflets are arranged on either side of the central stalk, like barbs on a feather, the leaf is said to be **pinnate**. Of these leaves there are two varieties, viz. **imparipinnate** or unequally pinnate, when there is an odd lobe at the extremity (Fig. 129), and

FIG. 126. — Cuneate leaflet from the leaf of the Horse Chestnut.

FIG. 127.—Sagittate leaf of *Convolvulus arvensis*.

FIG. 128. — Hastate leaf of *Rumex acetosa*.

paripinnate, or equally pinnate, when the number of lobes present is even (Fig. 130).

When a simple leaf is divided in a pinnate manner, it is **pinnatifid**, **pinnatipartite**, or **pinnatisected** (Fig. 131), according to the depth of the incisions. When a pinnatifid leaf has its terminal lobe large and rounded, and the side lobes gradually getting smaller towards the base (Fig. 113), it is **lyrate**; whilst if the terminal lobe is triangular, and the lobes are also angular (Fig. 111), it is **runcinate**.

When each of the pinnæ of a pinnate leaf is itself pinnate, the leaf is said to be **bipinnate**. If the division be carried a step further, it is **tripinnate** (Fig. 133).

When the divisions of the leaf spread out like the fingers of a hand, the leaf is **palmate** (Fig. 134), **palmatifid** (Fig. 108), **palmatipartite** and **palmatisected** (Fig. 135).

When a palmatisected leaf is itself cut up into segments, it is **dissected** or **laciniate** (Fig. 136).

Sometimes the lateral lobes of a palmate leaf are themselves divided, giving the whole somewhat the appearance of a bird's foot (Fig. 137). The leaf is then **pedate**.

FIG. 130.—Paripinnate leaf of *Lathyrus macrorhizus* (with auriculate or ear-shaped stipules), the rachis ending in a point.

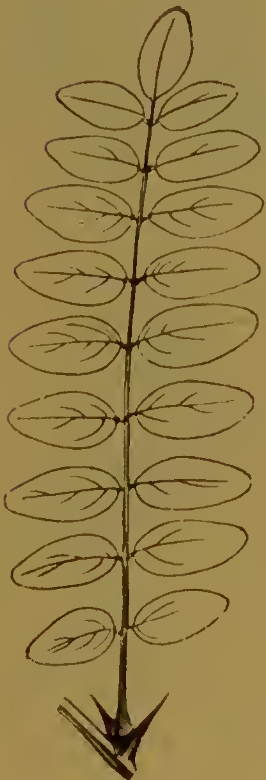

FIG. 129.—Imparipinnate leaf of the 'Acacia' (*Robinia Pseudacacia*) with opposite leaflets (and spinous stipules).

FIG. 131.—Pinnatisect leaf of the Common Poppy (*Papaver Rhœas*).

There are certain terms which are applied to the attachment of the leaves to the stem. Thus, when placed one above the

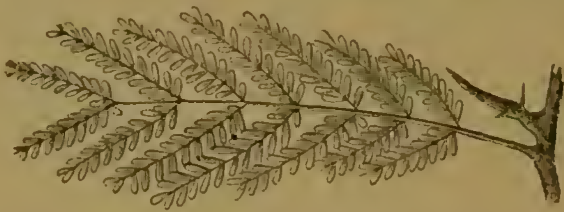

FIG. 132.—Bipinnate leaf of *Gleditschia triacanthos.*

other upon opposite sides of the stem, they are **alternate.** If placed in pairs on opposite sides, they are **opposite.** If the alternate pairs of opposite leaves are placed at right angles to

FIG. 133.—Tripinnate leaf of *Thalictrum.*

one another (Fig. 138), they are **decussate.** When there are more than two leaves forming a whorl round the stem (Fig. 139), they are said to be **verticillate.** When two opposite leaves have their bases so united as to form apparently but one (Fig.

140), often thus producing a cup, as in the Teasel, they are **connate.** If the base of the leaf, whether petiole, lamina, or stipules, embraces the stem, the leaf is **amplexicaul,** the part surrounding the stem being called the **vagina** or **sheath.**

FIG. 134.—Palminerved leaf of *Geranium pratense* (nature-printed).

FIG. 135.—Palmatisect leaf of the Monkshood (*Aconitum*).

FIG. 136. Heteromorphic leaves of the Water Crowfoot (*Ranunculus aquatilis*): the floating leaves trilobed, the submerged leaves laciniate.

FIG. 137. Pedate leaf of the Christmas Rose (*Helleborus niger*).

If the stem grows through the leaf, the latter is said to be **perfoliate** (Fig. 141), whilst, if any part of the leaf adheres to the stem, causing the latter to be winged (Fig. 142), the leaf is said to be **decurrent.**

If the leaves grow from the point of junction of the root

FIG. 138.—Decussate leaves of the Scarlet Pimpernel (*Anagallis arvensis*), with axillary flowers.

FIG. 139. — Verticillate leaves of the Madder (*Rubia tinctorum*).

FIG. 140.—Connate leaves of the Honeysuckle.

and stem, or if the stem be so reduced as to be almost obliterated, they are said to be **radical**. Leaves growing from the main stem are called **cauline**, and those from the branches, **ramal**.

FUNCTIONS OF THE LEAVES.

1. **To absorb food for the plant.**—We have already seen how the roots take up from the soil the various substances needed for the life of the plant. One very important substance, however, is not taken up by the roots of green plants, and this is carbon.

This element exists in the atmosphere in the form of carbon dioxide, or carbonic acid gas, a compound of carbon and

FIG. 141.—Perfoliate leaf of *Bupleurum rotundifolium.*

FIG. 142.—Decurrent leaf of *Symphytum officinale*, the stem hence becoming winged on one side.

oxygen, CO_2. It is produced wherever breathing, burning, and decay of organic bodies are taking place.

The composition of a thousand parts, by volume, of atmospheric air is as follows:—

Nitrogen (and Argon)	779·60.
Oxygen	206·10.
Water (variable)	14·00.
Carbon dioxide	0·30.
Various gases	traces.
	1,000·00.

That is to say that a thousand cubic feet of air contain not quite half a cubic foot of carbonic acid. Small as this quantity may appear to be, it is the source of the carbon of the plant.

The carbon dioxide enters the leaf through the stomata. It was thought formerly that it also passed, in solution, through the cuticle, but recent experiments appear to negative this

view. Having passed through the stomata into the intercellular spaces of the mesophyll, the carbon dioxide, dissolved in the sap, enters into the protoplasm of the cells.

2. **To assimilate the food absorbed.**—In the chlorophyll-bearing cells of the mesophyll the carbon dioxide is decomposed, the carbon being united with the elements of water, carbohydrates being formed. The process, however, is not by any means so simple as this. Probably the carbon dioxide is broken up into carbon monoxide and oxygen ($2CO_2 = 2CO + O_2$), and the water into hydrogen and oxygen ($2H_2O = 2H_2 + O_2$). The oxygen liberated from the carbon dioxide and the water is returned to the atmosphere, and the hydrogen unites with the carbon monoxide to form a carbohydrate. The exact carbohydrate first formed is uncertain, probably a simple one, such as **formic aldehyde**, CH_2O, ($CO + H_2 = CH_2O$). From this or other similar simple forms, the more complex carbohydrates are built up. Apparently some form of sugar is first formed. Some of this is at once carried away to the growing parts of the plant, the rest is converted into the assimilation starch, which, by the action of diastase, is reconverted into sugar and removed to be stored up as reserve starch. This assimilation only takes place in the chlorophyll-bearing cells, and only under the influence of the light. If the plant is kept in the dark no carbon dioxide is decomposed and no oxygen is evolved. With regard to the formation of the **proteids**, or nitrogenous substances of the plant, there is much uncertainty as to the need of light. The general result of experiments, however, is to show that for their production also light is not directly required.

The nitrates which have been absorbed by the root are during their passage upwards deoxidised, and, combining with the carbohydrates, give rise to compounds known as amides, which consist of ammonia where a portion of the hydrogen is replaced by some compound of carbon and oxygen. The special amide formed is possibly asparagin, a substance which is crystallisable and is soluble in cell sap. It is found distributed very widely in plants, especially in growing shoots and rhizomes and tubes. This aparagin is sometimes formed by the decomposition of more complex nitrogenous compounds, but sometimes apparently by the union of the ammonia and carbohydrate, thus being the first step towards the making of protoplasm. Meanwhile the sulphate of calcium, taken in by the root, has been decomposed by oxalic acid formed in the leaves, the sulphur thus set free combines with the amide and some non-nitrogenous compounds, and various proteids are made, from which protoplasm is built up.

3. **As a breathing organ.**—Plants, like animals, carry on a process of respiration, *i.e.* they take in atmospheric oxygen,

which combines with the carbon and hydrogen of the tissues forming carbon dioxide and water, which are restored to the air. The respiration, however, of plants is much less than that of animals; it differs in its amount in various plants, and in the different parts of the same plant. The more energetic the growth, the greater the amount of respiration: hence it is especially well seen in quickly germinating seeds, and unfolding leaf and flower buds.

The oxygen passes into the interior of the plant by means of the stomata, and by the same openings the carbonic acid gas is passed out into the atmosphere. This change goes on continually, irrespective of the presence or absence of light. During the daytime the feeding by the decomposition of carbon dioxide and assimilation of the carbon is so greatly in excess of the respiratory act, that it completely overshadows it, and apparently nothing is going on but the decomposition of the carbonic acid; but in the night time, when, owing to the absence of the light, no assimilation is taking place, the breathing can be perceived.

4. **As an organ of transpiration.**—A large portion of the water which is taken in by the roots of the plant escapes by the leaves. By means of this evaporation the sap becomes thickened as it ascends the stem. The transpiration takes place by means of the epidermis, and especially through the stomata. The amount which is evaporated depends upon certain conditions, viz.:—

a. The state of the atmosphere. All other things being equal, more moisture will be given off in dry than in moist atmosphere.

b. The amount of light. The greater the light, the greater the transpiration.

c. The structure of the epidermis. In many succulent plants the epidermis is very thick, thus preventing an excess of evaporation.

d. There is a greater evaporation from the lower than the upper sides of the leaves.

The amount of water transpired is often very great, as is shown by experiments which were first performed by Hales in 1724. A Sunflower plant, $3\frac{1}{2}$ feet high, weighing 3 lbs., and with a surface of 5,616 square inches, exhaled a pint of water a day; a Cabbage plant with 2,736 square inches, 19 fluid ounces; a Lemon tree with 2,557 square inches, 6 fluid ounces.

The action of Wardian cases depends upon this continual

evaporation. By this means the water which evaporates collects on the glass, and running down once more, waters the plants.

The transpiration of plants also plays an important part in determining the humidity of the atmosphere where they grow. We always find that if there are forests of trees the atmosphere in the neighbourhood is moist; whilst, on the other hand, there have been numerous cases where the clearing of a tract of country has materially interfered with the rainfall, producing droughts.

5. **As organs of circulation.**—From the fact of transpiration follows the next, that the leaves tend to produce a flow of sap upwards. As evaporation takes place there is a continual flow of water up the wood to take its place: the greater the evaporation the more rapid the sap circulation. (See Chapter XII.)

The foregoing functions are performed by all leaves; the following, however, are exceptional.

6. **In some cases the leaves act as carnivorous organs.**—Some plants seem to possess the power of absorbing their nitrogen by means of organic compounds containing it. Good examples are to be seen in Venus's Fly-trap (Fig. 143) and the Sundews of our own country. If we examine the leaves of the latter plants, we find that their upper surfaces are covered with glandular hairs which, when touched, exude a few drops of a sticky liquid which adheres to the fingers, and will be drawn out into a fine thread.

If an insect settles upon the leaf it becomes arrested, and gradually the leaf folds over, enclosing it. It thus remains closed for a short time, and on opening again there is found merely the outer shell of the insect, all the nutritive part having been absorbed by the plant. The leaf seems to contain a substance analogous to, if not identical with, the pepsine of the animal stomach, which possesses the power of rendering nitrogenous substances soluble. Other carnivorous plants have the same power of absorbing organic food materials by their leaves in various ways.

7. **In some cases the leaves act as organs of support.**—We have already seen that parts of the leaf may be converted into tendrils (Figs. 93 and 104), thus twining round the organ of support and sustaining the stem. In the Tropæolum the leaf-stalk itself twines and supports the plant.

Parasites.—It has been noted (page 35) that some plants obtain their food through the medium of others. Such plants

are known as parasites. We may divide them under three heads.

FIG. 143.—Venus's Fly-trap (*Dionæa muscipula*).

(*a*) **Semi-Parasites.**—These can obtain some food from the soil, but not sufficient to enable them to grow in a luxuriant manner.

If some seeds of Yellow Rattle be allowed to germinate in earth they will grow, but the plants will not be fully developed.

If, however, the seeds be sown amongst some grass, strong, well-developed Rattles will be obtained. The Rattle sends its roots into the roots of the grass and draws sap out of them, which is afterwards elaborated in its own leaves.

(*b*) **Green Parasites.**—Mistletoe (Fig. 60) is a type of this class. It cannot obtain any nourishment for itself out of the soil, and has to depend entirely upon the tree into whose stem it sends its roots. At the same time its leaves contain chlorophyll, and hence it can decompose the carbon dioxide of the atmosphere, and assimilate food for itself.

(*c*) **Perfect Parasites.**—Of this group the Broom Rape and Dodder are types. These plants possess no chlorophyll, hence they cannot decompose the atmospheric carbon dioxide, so they obtain from the plants on which they live sap which is already elaborated.

In the case of the Broom Rape the leaves are modified into scales destitute of chlorophyll, whilst in the Dodder leaves are entirely absent.

CHAPTER IX.

BRACTS AND INFLORESCENCE.

The term **bract** is employed for those leaves in whose axils flower buds instead of leaf buds arise, or for any appendage growing upon the flower-stalk below the flower.

In some cases, as in the White Dead Nettle, bracts cannot be distinguished, except by their position, from the true leaves of the plant; in other cases, whilst still leaf-like, they differ in shape from the other leaves of the same plant. In all these cases the bracts are said to be foliaceous or leafy bracts.

Sometimes the bracts are coloured, being then often mistaken for the true flowers, as in some species of Euphorbia. In other cases the bracts are small and scale-like.

Fig. 144.—Capitulum of Marigold, with imbricate involucre.

When several bracts surround a single flower as in the Pink, or a head of flowers as in the Marigold (Fig. 144), they form an **involucre**.

When a single bract is enlarged and ensheathes a single flower whilst in the young state, as in the Narcissus and Snow-flake, or a head of flowers, as in the Cuckoo-pint or Palm, it is called a **spathe**.

When bracts are scaly, they are said to be **squamous**, and the special scaly bracts which enclose the flowers of the Grass and Sedge tribes are **pales** and **glumes**.

If the bracts fall before, or soon after, the flower opens, they

are **deciduous** ; whilst if they remain (sometimes even to the ripening of the fruit), **persistent.**

If bracts be present, the plant is said to be **bracteate** ; if absent, **ebracteate.**

The term **inflorescence** is employed to describe the arrangement of the flowers upon the stem. In some cases, as in the

FIG. 145.—Simple raceme of *Antirrhinum majus.*

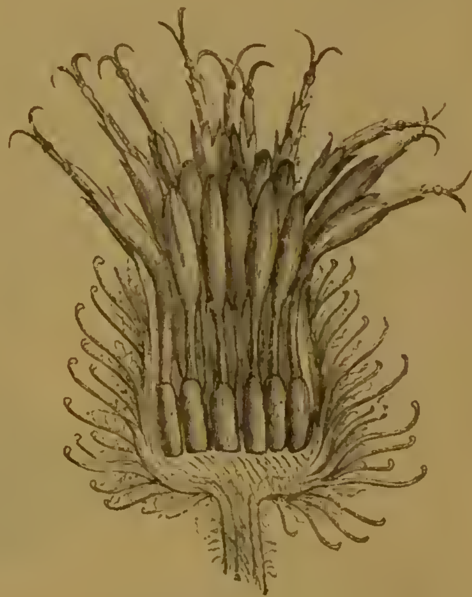

FIG. 146.—Longitudinal section through the capitulum of the Burdock (*Arctium Lappa*).

Tulip, there is a single flower at the top of the stalk, no others being formed below. The inflorescence is then said to be single-flowered. More often there are several flowers variously arranged. Inflorescences are divided under two heads.

If we examine such a bunch of flowers as the Snapdragon (Fig. 145), or Wallflower, or Stock, we find that the oldest flowers are towards the base, the younger ones being towards the apex. Such an inflorescence is said to be **indefinite.** Sometimes in the indefinite inflorescences, as in the Burdock (Fig. 146), or Thistle, or Dandelion, the flowers instead of being arranged one above another are side by side. In this case the younger flowers are towards the centre, and the older ones around them, and hence the indefinite inflorescence is also spoken of as **centripetal,** or centre-seeking. In the Pink, on the other hand (Fig. 147), the stalk is capped by a flower which is the

first to open, the younger ones budding below it. This is termed **definite inflorescence**, or (since, when the flowers are on the same level, the older ones will be towards the centre, and the younger ones outside) **centrifugal**.

Of each of these forms there are several varieties.

Fig. 147.—*Dianthus Caryophyllus*: portion of plant with definite inflorescence.

Fig. 148.—Simple spike of *Verbena officinalis*.

Indefinite or Centripetal Inflorescence.—In the case of the indefinite inflorescence the axis may either be lengthened as in the Snapdragon, or arrested as in the Burdock and Dandelion; and in either case the flowers may be sessile or stalked.

A **spike** is an indefinite inflorescence with a lengthened axis and sessile flowers, as in the Verbena (Fig. 148), Plantain, or Wheat.

A **raceme** is an indefinite inflorescence with a lengthened axis and stalked flowers, as in the Snapdragon (Fig. 145) and Currant (Fig. 149).

A **capitulum** is an indefinite inflorescence with shortened

axis and sessile flowers, as in the Marigold (Fig. 144), Burdock (Fig. 146), and Dandelion.

An **umbel** is an indefinite inflorescence with shortened axis

FIG. 149.—Simple raceme of the Currant.

FIG. 150.—Simple umbel of the Cherry.

and stalked flowers, as in the Ivy. If each branch of the umbel be itself branched, the **compound umbel** is produced, as

FIG. 151.—Compound umbel of Fool's Parsley (*Æthusa Cynapium*); common involucre wanting; involucels of three leaves each.

in the Fool's Parsley (Fig. 151). Generally the capitulum and umbel are surrounded by an involucre of bracts, and sometimes the secondary branches of the compound umbel have a special involucre which is called the **involucel**.

Special names are given to varieties of some of these forms.

VARIETIES OF SPIKE.

A **catkin**, or **amentum**, is a deciduous spike of unisexual flowers, as in the Oak (Fig. 152), Hazel, or Willow.

A **spadix** is a fleshy spike bearing several unisexual flowers, the whole enveloped in a spathe, as in the Arum (Fig. 153).

FIG. 152.—Catkin or amentum of the Oak.

FIG. 153.—Spadix of Arum: *a*, barren stamens; *b*, stamens; *c*, pistils.

FIG. 154.—Cone of the Scotch Fir.

A **strobilus** is a spike of unisexual flowers with membranous bracts, as in the Hop.

A **cone** is a spike of unisexual flowers with lignified bracts, as in the Fir (Fig. 154).

VARIETIES OF RACEME.

A **corymb** is a raceme where the stalks or pedicels are of different lengths, the lower ones being the longest, so that the flowers form a flat-topped head, as in the Hawthorn and some species of Cerasus.

A **panicle** is a compound raceme, that is, one where each branch is itself branched, as in some Yuccas.

A **thyrsus** is a panicle with very short pedicels, as in the Horse Chestnut and Lilac.

VARIETY OF CAPITULUM.

The **hypanthodium** has the end of the stalk hollowed out, the flowers growing within, as in the Fig (Fig. 155).

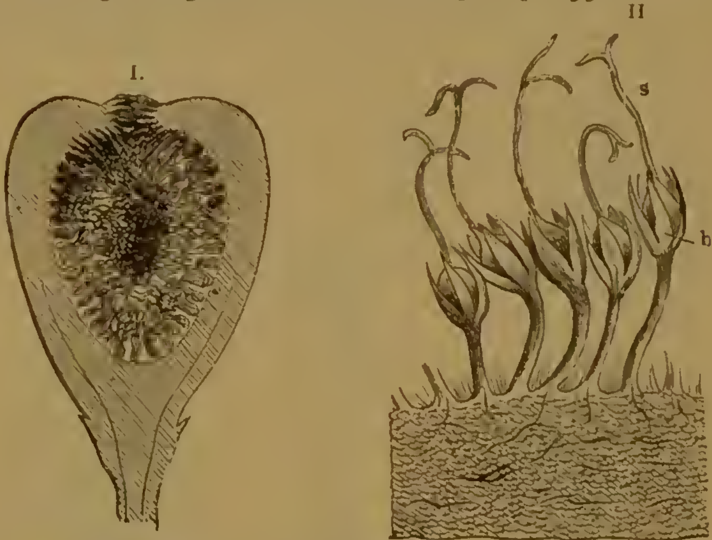

FIG. 155.—I. Longitudinal section through the hypanthodium of a Fig, exposing the flowers in its interior. II. A piece with five female flowers: *s*, pistil; *b*, perianth.

We may tabulate the forms of indefinite inflorescence as follows:—

Indefinite Inflorescence.

	With lengthened axis.		With shortened axis.	
	With sessile flowers.	With stalked flowers.	With sessile flowers.	With stalked flowers.
	SPIKE.	RACEME.	CAPITULUM.	UMBEL.
Varieties	Amentum.	Corymb.	Hypanthodium.	Compound umbel.
	Spadix.	Panicle.		
	Strobilus.	Thyrsus.		
	Cone.			

Definite or Centrifugal Inflorescence.—The general name for these is **Cyme**. We cannot well tabulate them in the same way that we do the indefinite. In many cases we employ the name of the indefinite inflorescence as an adjective to qualify the term cyme. Thus we have a **spiked cyme** in Sedum, **racemose cyme** in Campanulas, **panicled cyme** in Privet, **corymbose cyme** in Laurustinus, etc.

The **dichotomous cyme** or **Dichasium** (Fig. 156) is one where two branches spring from beneath the terminal flower, each in its turn capped by a flower and developing two branches just below it, as in the Chickweed and Centaury. If there be three stalks the cyme is **trichotomous.**

If but one stalk be given off, which is again branched on

FIG. 156.—Dichotomous cyme of *Cerastium.*

FIG. 157.—Cymose inflorescence of *Myosotis.*

the same side, and this again repeated a number of times always on the same side, so that the young flowers become coiled like a scorpion's tail or a shepherd's crook, the **scorpioid cyme** is formed, as in the Forget-me-not, and many of the Boraginaceæ (Fig. 157).

The **fascicle** is a cyme which has a large number of flowers on short stalks, as in the Sweet William.

The **glomerulus** is a cyme with a large number of sessile flowers, as in the Box.

The **verticillaster** consists of two cymose bunches placed on opposite sides of the stem, so as apparently to produce a whorl, as in the *Lamium album* (Fig. 158), and other members of the Labiatæ.

Mixed Inflorescences.—Sometimes in a plant there is a mixture of the two kinds of inflorescence. Thus in the Dead Nettle, whilst each separate inflorescence is definite, being a verticillaster, yet, taking the whole plant, the arrangement is indefinite, the lower verticillasters opening first. On the other

FIG. 158.—Verticillaster of *Lamium album*.

hand, in most of the members of the natural order Compositæ, whilst each capitulum is itself indefinite, yet, taking the plant as a whole, the arrangement is definite, for the terminal capitulum is the first to open.

Such an inflorescence is said to be mixed.

CHAPTER X.

STRUCTURE AND FUNCTIONS OF PARTS OF THE FLOWER.

THE **flower** is that part of the plant which **subserves** the **purposes of reproduction.**

When complete, the flower consists of four whorls or series of organs. The two outer ones are merely coverings, whilst the inner ones form the essential organs.

Commencing at the exterior, the outer coat is known as the **calyx** (Fig. 159, K), and each division of which it is made up is a **sepal.** The inner coat is the **corolla** (Fig. 159, B), and each separate part of it a **petal.**

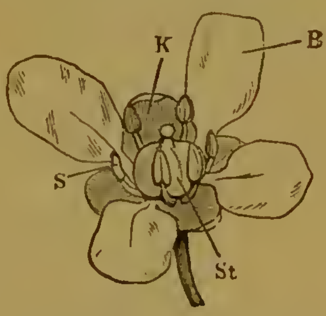

FIG. 159.—Flower of *Sisymbrium Alliaria:* K, calyx; B, corolla; S, stamens; *st*, pistil.

If both coats be present, as in the Buttercup, the flower is said to be **dichlamydeous**; if only one, as in the Anemone, **monochlamydeous**; if both be absent, as in the Ash, **achlamydeous.**

The outermost whorl of the essential organs of the flower is the **andrœcium** (Fig. 159, S), consisting of one or more **stamens**; whilst within there is the **pistil** or **gynœcium** (Fig. 159, S*t*), consisting of one or more **carpels.**

This will be a convenient place to note the distinction that is drawn between a complete and a perfect flower.

For a flower to be **complete,** all four of the whorls must be present; if any one be absent, the flower is **incomplete.** On the other hand, the term **perfect** is applied to all those flowers in which both andrœcium and pistil are present, although, as in the Anemone, one of the coats may be wanting, or even, as in some flowers of the Ash, both coats may be absent. An

imperfect flower is one where there is only one whorl of the essential organs, as in the Hazel and Oak.

It follows that every complete flower must be perfect, but every perfect flower is not necessarily complete; on the other hand, every imperfect flower must be incomplete, but every incomplete flower is not imperfect.

Perfect flowers are sometimes spoken of as **hermaphrodite.** Imperfect flowers are either **staminate** (Fig. 160) if the pistil be absent, or **pistillate** (Fig. 161) if the stamens be absent.

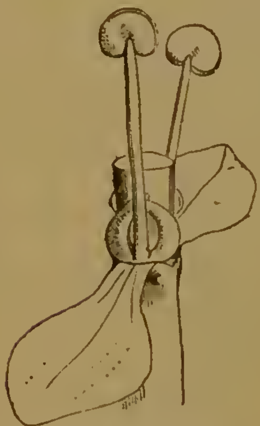

Fig. 160.—Staminate (♂) flower of *Callitriche verna*, with two sickle-shaped bracts.

Fig. 161. Pistillate (♀) flower of *Callitriche verna*.

Fig. 162.—The Hazel (*Corylus Avellana*); branch with male and female flowers.

If staminate and pistillate flowers grow upon the same plant, as in the Hazel (Fig. 162), Oak, and Birch, the plant is said to be **monœcious**; if they grow upon separate plants, as in the Willow (Fig. 163), Juniper, and Poplar, it is **diœcious**;

whilst if on the same plant are to be found hermaphrodite, staminate, and pistillate flowers, as in the Ash, it is **polygamous**.

We must now notice each part of the flower more particularly.

FIG. 163.—Sallow (*Salix caprea*). I. Male catkin. II. Female catkin.

FIG. 164.– Flower of the Strawberry, with calyx in two rows.

FIG. 165.—Longitudinal section through the flower of *Ranunculus acris*, showing the hypogynous calyx, corolla, and stamens.

CALYX.—The sepals are generally arranged in one whorl, but in some cases, as in the Strawberry (Fig. 164), there may be two (or even, as in the Cotton, three) whorls.

Generally the sepals are green, but sometimes, as in the Fuchsia, Larkspur, and Garden Nasturtium, they are coloured, or petaloid.

When the calyx is inserted beneath the ovary upon the end of the flower-stalk (which is known as the **thalamus**), it is said to be **inferior**, and the ovary is **superior**, as in the Ranunculus (Fig. 165, and Fig. 166, H and P).

In other cases the calyx is adherent to the sides of the

ovary, only the free limb springing from its upper part (or the calyx springs entirely from the top of the ovary). It is then said

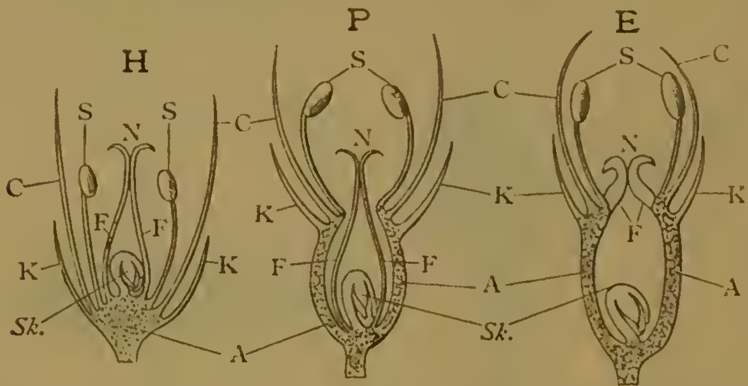

FIG. 166.—Diagrammatic section of hypogynous (**H**), perigynous (**P**), and epigynous (**E**) flowers. A, axis, forming convex or concave receptacle, or wall of ovary: K, calyx; C, corolla; S, stamens; F, carpels; N, stigma; *Sk*, ovules. (After Prantl.)

to be **superior**, and the ovary is **inferior** (Fig. 166, E), as in the Fuchsia, Willow Herb, etc.

When the sepals of the calyx are distinct from one another,

FIG. 167.—Spurred calyx of *Tropæolum*.

FIG. 168.—Caducous calyx of Poppy.

as in the Strawberry (Fig. 164), it is said to be **polysepalous.** If the sepals be united together (Fig. 170), as in the Primrose, the calyx is **gamosepalous.**

When the sepals are alike, as in the Buttercup (Fig. 165), or Primrose, the calyx is said to be **regular**; if some be differently

developed from the rest, the calyx is **irregular**, as in the Garden Nasturtium (Fig. 167).

If, as in the Poppy (Fig. 168), the calyx falls off as soon as the flower-bud opens, it is said to be **caducous**; if, as in the Ranunculus (Fig. 165), it remains after the flower opens, but falls off before the fruit ripens, it is **deciduous**; whilst if it remains after the fruit has ripened, it is **persistent**, as in the Strawberry (Fig. 164).

FIG. 169.—Tubular calyx.

FIG. 170.—I. Turbinate. II. Urceolate calyx (represented diagrammatically).

FIG. 171.—Saccate calyx of *Lunaria*.

Sometimes the persistent calyx becomes very much enlarged around the fruit; it is then **accrescent**, as in the Physalis.

There are also certain terms which are used in describing the shape of the calyx which are of great importance in Descriptive Botany.

Thus it may be **tubular** (Fig. 169), as in the Centaury; **urceolate** (Fig. 170, II.), or urn-shaped, as in the Campion; **inflated**, or swollen, as in the Bladder Campion; **turbinate** or top-shaped (Fig. 170, I.); **funnel-shaped** or **infundibuliform** (Fig. 176), as in the Deadly Nightshade; **saccate** (Fig. 171), if there are four sepals, two of which are prolonged at the base, as in most cruciferous plants; **rotate** (Fig. 164), as in the Strawberry; **bilabiate** or **two-lipped** (Fig. 177), as in the Dead Nettle; **spurred** (Fig. 167), as in the Tropæolum; **galeate** or **hooded** (Fig. 172), as in the Monkshood.

When the calyx is polysepalous, it should be described as **bisepalous, trisepalous**, etc. If gamosepalous, it may be described as **toothed, lobed**, or **incised**, according to the depth to which it is cut.

A remarkable form of calyx known as **pappus** is met with amongst the composite and some other flowers. In this case

the sepals are converted into numerous hairs, which crown the ovary, and are often very much enlarged upon the fruit, as is seen in the head of the Dandelion after flowering.

The hairs may be either simple, when the pappus is **pilose**

FIG. 172.—Monkshood (*Aconitum Napellus*). Part of plant, showing galeate calyx.

FIG. 173.—Pilose sessile pappus of *Senecio.*

FIG. 174.—Pilose stipitate pappus of Dandelion.

(Figs. 163 and 174), or feathery, when it is **plumose** (Figs. 175 and 178). Again, they may be **sessile** upon the ovary (Figs. 173 and 175), or stalked, when they are said to be **stipitate** (Figs. 174 and 178); so that there are four forms of pappus, viz:—

Pilose sessile, as in Groundsel.
Pilose stipitate, as in Dandelion.
Plumose sessile, as in Salsify or Goatsbeard.
Plumose stipitate, as in Thistles.

In the Chicory and Tansy (Fig. 179) the pappus is **coronate**, forming a crown of broad hairs above the fruit.

Corolla.—The second enveloping layer of the flower is

Fig. 175.—Plumose sessile pappus of *Tragopogon*.

Fig. 176.—Deadly Nightshade (*Atropa Belladonna*): flower.

Fig. 177.—Bilabiate five-toothed calyx of *Lamium*.

Fig. 178.—Pappus of *Carlina vulgaris*, the feathery rays united below into several bundles and coherent at the base into a ring.

Fig. 179.—Fruit, *f*, of the Tansy (*Tanacetum vulgare*), surmounted by the coronate pappus.

generally more delicate in its structure than the calyx, and is often highly coloured and possesses odour. If there be only one coat present, as in the Anemone and Marsh Marigold, whatever its appearance, it is spoken of as calyx.

The corolla is either **gamopetalous** or **polypetalous**—**regular** or **irregular.**

If the petals are attached with the calyx beneath the ovary (Fig. 166, H), the corolla is said to be **hypogynous**; if the ovary be superior, but the petals, instead of being inserted under it, are attached upon the calyx, forming a ring round the ovary, the corolla is **perigynous** (Fig. 166, P). When the ovary is

inferior and the corolla springs from the top of it with the calyx (Fig. 166, E), it is **epigynous.**

The corolla never remains to form a part of the fruit, as the calyx does sometimes.

Terms are also employed to describe the shape of the corolla, and of the individual petals.

When the petals are broad above and form a narrow limb

FIG. 180.—Unguiculate petal of *Dianthus*, with toothed lamina.

FIG. 181.—Bifid unguiculate petal of *Lychnis*, with ligule.

FIG. 182.—Tubular corolla from the disc of the capitulum of *Centaurea Cyanus*.

below, as in the Pink (Fig. 180) and Lychnis (Fig. 181), they are said to be **unguiculate**, or **clawed.**

When each petal is notched at its free edge, as in the Lychnis (Fig. 181), it is described as **bifid.** If there are several notches it is **toothed** (Fig. 180), or, if very much divided, **fimbriated,** as in *Dianthus plumarius.*

Again, the corolla may be **tubular,** as in the Bluebottle and other composite plants (Fig. 182); **campanulate,** or bell-shaped, as in the Campanula (Fig. 183); **urceolate,** or urn-shaped, as in the Bilberry (Fig. 184); **globose,** as in many Heaths (Fig. 185); **infundibuliform,** or funnel-shaped, as in the Convolvulus (Fig. 186); **hypocrateriform,** or salver-shaped, with the petals flattened above, as in the Jasmine (Fig. 187); **rotate,** or wheel-shaped, as in the Borage (Fig. 188); **cruciform,** or cross-shaped, when there are four petals arranged like a Maltese cross, as in the Wallflower, Stock, or Lunaria (Fig. 189); **ligulate,** or strap-shaped, when the lower part of the corolla forms a tube and the upper part is flattened out, as in the Globularia (Fig. 190), and the ray florets of the Daisy and florets of the Dandelion;

FIG. 183.—Campanulate corolla of the Canterbury Bell.

FIG. 184.—Urceolate corolla of *Vaccinium Myrtillus.*

FIG. 185.—Globose corolla of *Erica Tetralix.*

FIG. 186. — Infundibuliform corolla of *Convolvulus arvensis.*

FIG. 187. — Hypocrateriform corolla of the Jasmine.

FIG. 188.—Rotate corolla of the Borage (*Borago officinalis*).

FIG. 189. — Cruciform flower of *Lunaria*, with unguiculate petals.

FIG. 190.—Ligulate corolla of *Globularia Alypum.*

FIG. 191.—Bilabiate ringent corolla of *Lamium album.*

FIG. 192.—Bilabiate personate corolla of *Antirrhinum majus.*

spurred, as in the Violet and many Orchids; **bilabiate**, or two-lipped, as in the Dead Nettle (Fig. 191),—of this there are two forms: if the lips are wide apart, as in the Dead Nettle, it is **ringent**; if closed, as in the Snapdragon (Fig. 192), it is **personate**;—**papilionaceous**, or butterfly-shaped, as in the Laburnum and other members of the Pea-flower tribe (Fig. 193). In this case there are five petals—one overlooking the rest, the *standard*, or *vexillum* (Fig. 193, III.); one standing out on each

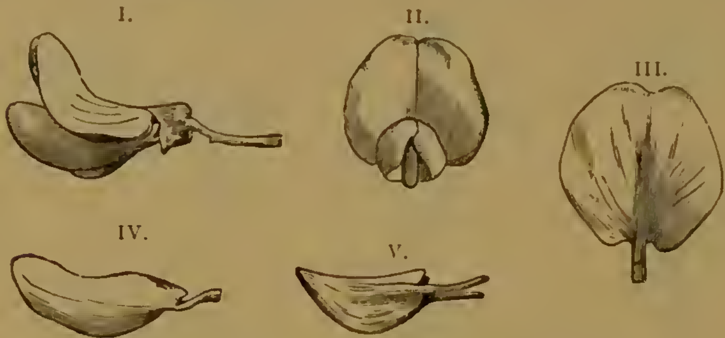

FIG. 193.—Papilionaceous corolla of Laburnum. I. Seen laterally. II. In front. III. Standard. IV. Left wing seen from without. V. Keel.

side, the *wings* or *alæ* (Fig. 193, IV.); and two united surrounding the stamens, the *keel* or *carina* (Fig. 193, V.).

In some cases, as in many of the Orchids, there is a most irregular shape of corolla which has received no special name. The term **caryophyllaceous** is applied to the corolla, as it is met with in the Pink tribe (Figs. 194 and 195), when there are five petals attached by claws to the base of a tubular calyx; whilst if there are five petals, not clawed, and attached in a perigynous manner (Fig. 196), the corolla is **rosaceous.**

The symmetry of flowers varies. In some cases, as in the Buttercup and Rose, the flower can be divided into similar halves in more than two planes. It is then said to be **radially symmetrical** or **actinomorphic.** In other cases it can be divided into two similar halves in only one, or, at the most, two planes. In this case it is spoken of as being **bilaterally symmetrical.** Of this there are two forms. If it can be divided into two similar halves in two planes, it is described as **isobilateral**—example, Wallflower; if in only one plane, **zygmorphic**; example, Sweet Pea or Dead Nettle.

A flower which cannot be divided into two similar halves in any direction is **asymmetrical.**

There are sometimes attached to the corolla subsidiary

organs, which are variously arranged, and which, owing to their not being universally present, are not treated of as a separate whorl. They form the **corona** or **paracorolla**, and are petaloid and well developed in the Narcissus (Fig. 187), or small as in the Lychnis (Fig. 194), or consist of several hairs as in the Passion

FIG. 194.—Caryophyllaceous corolla of *Lychnis vespertina*, with corona.

FIG. 195.—Longitudinal section through the caryophyllaceous corolla of *Dianthus*.

FIG. 196.—Longitudinal section through the rosaceous flower of the Rose; the pistil seated in the base of the urceolate calyx.

FIG. 197.—Petaloid perianth of *Narcissus*, with 6-partite limb and campanulate corona.

Flower and Dead Nettle, or scales with glandular hairs attached as in the Grass of Parnassus (Fig. 199), or scales known as **staminodes** closing the tube of the corolla as in the Borage (Fig. 198).

NECTARIES, or glands for the secretion of honey, are sometimes spoken of as subsidiary organs, but various parts of the

flower may be specially developed for this function. Thus, there may be scales between the stamens as in the Grape Vine (Fig. 200), or spurs either of the calyx as in the Tropæolum (Fig. 167), or of the corolla as in the Valerian (Fig. 201), or of

Fig. 198.—Longitudinal section through the flower of the Borage: each bifid stamen bears the anther on its inner half, while the other half forms an erect scale.

both as in the Larkspur (Fig. 202), or of the stamens as in the Violet (Fig. 204). There may be specially developed petals, as in the Monkshood (Fig. 203); or glands in hollows at the base of the petals, as in the Buttercup.

Perianth.—The term **perianth** is generally employed in those cases where the calyx and corolla resemble one another,

Fig. 199.—I. Longitudinal section through the flower of *Parnassia palustris*. II. One of the petals; a glandular scale belonging to the corona attached to it in front.

being both green or both petaloid, especially when it occurs among monocotyledonous plants. In this case we speak of it as being **gamophyllus** of **polyphyllous**. (Some botanists use the term perianth for describing the flowers which possess only one floral envelope.)

Æstivation.—Just as the terms *vernation* and *præfoliation*

FIG. 200.—Stamens and pistil of the Grape Vine, with a honey gland (nectary) between each pair of stamens.

FIG. 201.—Spurred corolla of *Valeriana*.

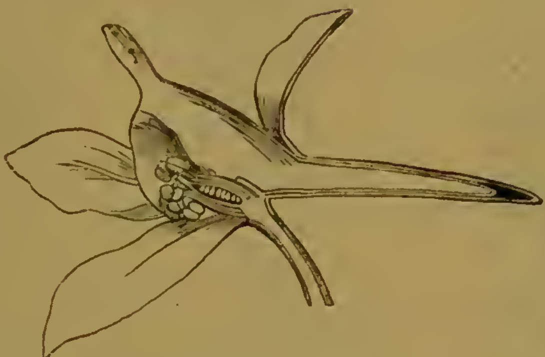

FIG. 202.—Longitudinal section of flower of Larkspur, with spurred calyx and corolla.

FIG. 203.—Monkshood (*Aconitum Napellus*). Flower, the coloured calyx having been removed, showing the two petals, *a*, developed into nectaries, the remaining petals being reduced to scales or altogether abortive.

are applied to the arrangement of the foliage leaves in the bud, so the terms **æstivation** and **præfloration** are employed to describe the arrangement of the leaves in the flower-bud. The same terms already employed (see Chapter VII.) can also be used in this case. Besides these, however, we apply the term **vexillary** to the æstivation as seen in a papilionaceous plant (Fig. 205), and **crumpled** when the petals are crumpled up as in the Poppy.

FIG. 204.—Spurred stamens of Violet.

FIG. 205.—Vexillary æstivation of Papilionaceæ.

ANDRŒCIUM.—We now come to the first whorl of the essential organs of the flower. Each **stamen** of which the andrœcium is composed consists, when complete, of **two parts,**

FIG. 206.—Monadelphous stamens of *Malva*.

FIG. 207.—Diadelphous stamens of *Lathyrus*; nine filaments united into a sheath at the base, one free.

FIG. 208.—Polyadelphous stamens of Orange.

viz. the stalk which attaches it to the rest of the flower, and which is known as the **filament**, and the knob on the summit, which is in reality a little box, the **anther**. The anther usually consists of two lobes within each of which there are two cavities, the **pollen sacs** or **microsporangia**, which contain a fine powder, the **pollen** or **microspores**—which is the essential part of the stamen. The division wall between the two pollen sacs in each anther is ruptured either when the anthers open, or even earlier, making the anther bilocular.

These stamens may be either distinct, when they are said

to be **free**, as in the Ranunculus (Fig. 165), or they are more or less united.

If they are united by means of their filaments into one bundle, whilst their anthers are free, as in the Mallow (Fig. 206), they are said to be **monadelphous**.

If there be two bundles, as in the sweet Pea (Fig. 207), the

FIG. 209.—Syngenesious anthers of Thistle; the filaments free.

FIG. 210. — Stamens of *Aristolochia* sessile upon the stigma.

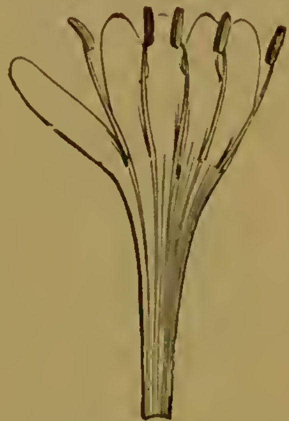

FIG. 211.—Section of corolla of Honeysuckle, with epipetalous stamens.

andrœcium is **diadelphous**; and if more than two bundles, as in the Orange (Fig. 208), **polyadelphous**. If the stamens are attached together by means of their anthers, whilst the filaments are free, as in the Thistle and other composite plants (Fig. 209), they are **syngenesious**. If the anthers are attached immediately upon the pistil, as in the Birthwort (Fig. 210) and various Orchids, they are **gynandrous**.

With regard to the attachment of the stamens, we apply the same terms which we used in describing the position of the corolla. Thus the stamens may be **hypogynous** (Fig. 166, H), **perigynous** (Fig. 166, P), or **epigynous** (Fig. 166, E). In addition to these positions the stamens may be upon the corolla, when they are said to be **epipetalous** (or **epiphyllous** when there is a perianth), as in the Honeysuckle (Fig. 211). If the filament of the stamens be absent, as in the Verbena (Fig. 212), the anthers are said to be **sessile**.

More often there is a filament present which is generally

thin and thread-like, but sometimes, as in some of the stamens of the Water Lily, it is broad and flat. Generally the various filaments are about the same length, but in some cases there is a constant difference between the stamens on this point. Thus in the Mustard (Fig. 213), and allied plants of the natural order Cruciferæ, there are four long and two short stamens, when they are said to be **tetradynamous**; whilst in the Dead Nettle and most other plants of the order Labiatæ there are two long and two short, and the stamens are **didynamous** (Fig. 214).

FIG. 212. — Section of corolla of *Verbena*, with sessile epipetalous anthers.

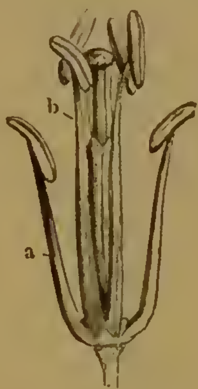

FIG. 213.—Tetradynamous stamens and pistil of *Brassica nigra*; *a*, shorter, *b* longer stamens.

FIG. 214.—Flower of *Lamium*, with didynamous stamens.

If the anthers are attached immediately upon the top of the filaments they are said to be **innate**, or **basifixed**, in their attachment. If the filament is prolonged up behind the anthers they are **adnate**, or **dorsifixed**; and if it be attached loosely to the centres of the anthers, so that they swing upon the point of attachment, as in the Wheat (Fig. 215), they are **versatile**.

The portion of the filament to which the anthers are attached is called the **connective**. Usually this is not developed to a noticeable degree, but in the Herb Paris it is prolonged beyond the anthers, giving them the appearance of being placed halfway down the stamen.

In the Hornbeam the connective is divided into two equal branches, each of which bears an anther lobe (Fig. 216), whilst in the Sage (Fig. 217) the branches of the connective are unequal in length; the long one bears a perfect anther lobe, whilst the short one has an abortive anther, or one destitute of pollen.

The surface of the anther to which the connective is attached is known as its **back**, whilst the other side is called the **face.** This is generally grooved, showing the point of attachment of the lobes. When the face is turned towards the pistil the stamens are said to be **introrse** ; when towards the petals, **extrorse.**

At first the anther is a solid mass of cells. Then a mass of meristem cells is formed just below the epidermis. The central ones form the **Archesporium** from which the pollen grains are formed : outside this the cells form three layers ; the inner one is known as the **Tapetum**, the outer the **fibrous layer**, and between them the **intermediate layer**, which very soon disappears. The cells of the tapetum are specially rich in protoplasm, and serve as food for the young pollen grains while developing. The cells of the archesporium divide for a time, and then the division ceases for a while. The cells become separated from one another, and float in a liquid which is produced by the disintegration of the cells of the tapetum. They are now spoken of as the **mother cells** of the pollen grains.

FIG. 215. — Stamen of wheat with versatile anther, *b*, lightly fixed at the extremity of the filament, *a*.

FIG. 216.—Stamen of Hornbeam (*Carpinus Betulus*), with branching connective.

FIG. 217. — Stamen of *Salvia*, with connective branching into two arms of very unequal length, the right-hand arm bearing an abortive anther.

The next step differs slightly in the two great divisions of Dicotyledons and Monocotyledons. In Dicotyledons the nucleus of each mother cell divides into two by a process of karyokinensis, and then each daughter nucleus divides into two, so that four nuclei are formed in each mother cell. Then cell walls are formed between the nuclei, so that the mother cell finally forms four **special mother cells.**

In Monocotyledons, instead of the four nuclei being formed before the cell walls are produced, ordinary cell division takes place. First, the mother cell divides into two, and then each of

the cells thus formed divides so as to produce the four special mother cells.

Finally, in both cases, the protoplasm of each special mother cell surrounds itself with a cellulose coat forming the **pollen grain** or **microspore**. The walls of the mother cells and special mother cells are disintegrated, so that the grains lie free in the pollen sacs. Sometimes, however, the wall of the special parent cells is not quite absorbed, and there is formed a compound body of four pollen cells united, whilst in the Orchids the pollen

I. II III. IV.

V.

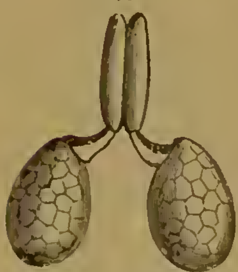

FIG. 218.—Pollen grains. I. *Cucurbita.* II. *Passiflora.* III. *Cuphea platycentra.* IV. *Dipsacus fullonum.* V. Pollen-masses (pollinia) of *Cynanchum Vincetoxicum* (Asclepiadeæ).

cells of each lobe are completely united together, forming a pollen mass, or **pollinium** (Fig. 218, v.). Each pollen grain possesses two coats: the inner one, the **intine**, is complete; the outer one, the **extine**, is pierced by several openings, and is often variously ornamented by spines, protuberances, or reticulations (see Fig. 218). The protoplasmic contents of the cell, known as **fovilla**, contain sulphur and fat globules. In form the pollen granules are generally round; in the Chicory they are polyhedral; in the Evening Primrose, triangular; in the Basella, cubical; in the Tradescantia, cylindrical; and in the Zostera, thread-like. In size they vary from $\frac{1}{200}$ to $\frac{1}{1000}$ of an inch. Generally the grains are yellow, in species of Mullein they are red, in some Willow Herbs blue, black in the Tulip, and in other plants green or of a whitish colour.

When the pollen is ripe the anther lobes open to let it fall out. They open or dehisce in various ways.

1. *Longitudinal dehiscence*, as in the Pine (Fig. 219) or Tulip, when there is a slit running along the face of the anther from top to bottom. This is the commonest form.

2. *Transverse dehiscence*, generally met with in unilocular anthers, as the Lady's-mantle.

3. *Porous dehiscence*, openings being produced either at the apex of the lobe, as in the Rhododendron (Fig. 221); or in the side, as in the Heath (Fig. 223).

4. *Valvular dehiscence*, when a portion of the anther lobe lifts up like a trap-door, as in the Barberry (Fig. 220) or Bay (Fig. 222).

FIG. 219.—Stamen of *Pinus sylvestris*, with longitudinal dehiscence.

FIG. 220.—Stamen of Barberry, the anther opening by recurved valves.

FIG. 221.—Stamen of *Rhododendron*, each anther-lobe opening by a pore.

FIG. 222.—Stamen of Bay (*Laurus nobilis*), with two glands at the base of the filament, the anther opening by recurved valves.

GYNŒCIUM OR PISTIL.—Each of the **carpels** of which the pistil is made up consists, when complete, of a swollen basal portion, the **ovary**; above this a stalk or **style**, which is capped

FIG. 223. — Stamen of *Erica*, the anther opening by pores and bearing two appendages at its base.

FIG. 224.—Pistil of Lily, with ovary, style, and stigma.

FIG. 225. — Papillose stigma of *Statice*.

by the **stigma**. The ovary is a hollow box containing one or more rounded bodies, the **ovules** or **macrospoangia**. Generally the carpels of the pistil are united together, either entirely, as in the Lily (Fig. 224), or, as is often the case, the ovaries are united whilst the styles and stigmas are free, as in the Sea-lavender (Fig. 225). In these cases the pistil is said to be **syncarpous**. When the ovaries are distinct, as in the Buttercup (Fig. 165), it is **apocarpous** (when there is only one carpel to the pistil, as in the case of the Pea, it is also said to be **apocarpous**). If there is but one carpel, the pistil is said to be **monocarpellary**. A **bicarpellary** pistil has two carpels, a **tricarpellary** three, a **polycarpellary** pistil more than three.

In a syncarpous pistil we can often tell the number of carpels present by the separate stigmas (or styles) (Fig. 225). In other cases we find on making a section that the syncarpous ovary possesses several cells or loculi, each corresponding with a single carpel, so that from them we can count the number of carpels (Fig. 226). Sometimes we find that there is but a single loculus in the ovary, and we can then often tell the number of carpels by noticing in how many places the ovules are arranged (Fig. 227).

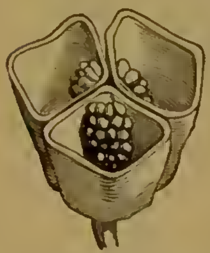

Fig. 226.—Capsule of *Colchicum*; transverse section.

Fig. 227.—Section of ovary of *Viola*.

In some few cases it is difficult or almost impossible to be able to say definitely in an individual plant how many carpels are present. The ovary, as we have seen, may be either **inferior** or **superior**. In the former case it is either inserted in the fleshy end of the flower-stalk, known as the **thalamus** or **receptacle**, so that the calyx springs from above it; or the calyx tube is adherent to the wall of the ovary, the free limb springing from the top. We often find two lines running down the ovary from apex to base. These are known as the **sutures**: the one towards the centre of the flower is the **ventral suture**, whilst the one turned towards the perianth is the **dorsal suture**.

When the pistil is apocarpous, each ovary contains but one cell, or is **unilocular**, although sometimes there are false partitions growing partially across the cell.

In syncarpous ovaries there are often numerous cells agreeing with the numbers of the carpels (Fig. 228, D), when the ovary is **bi-**, **tri-**, or **multi-locular**. In other cases there is

but one cell (Fig. 228, B), the ovary being **unilocular.** Sometimes there are partial dissepiments formed by an infolding of the edges of the carpels (Fig. 228, C). In some few cases there are actual divisions; thus the ovary of the Labiatæ and Boraginaceæ is originally bilocular, but by a subsequent division it becomes divided into four cells.

The ovules are not, as a rule, distributed indiscriminately over the surface of the ovary, but are arranged on certain parts of the wall, each of which is called a **placenta,** whilst the arrangement of the ovules is spoken of as **placentation.**

In the case of apocarpous pistils, where there are more

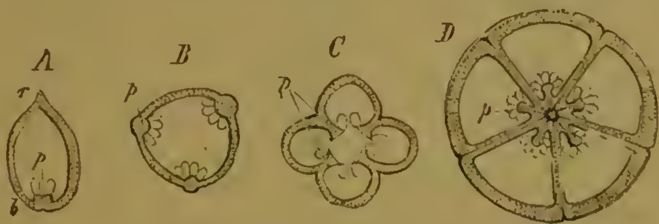

FIG. 228.—Diagrammatic sections of ovaries: *p*, the placenta, to which the seeds are attached; *A*, monocarpellary unilocular; *B*, polycarpellary unilocular; *C*, polycarpellary falsely multilocular; *D*, polycarpellary multilocular; *r*, dorsal suture, or midrib; *b*, ventral suture, or margins of carpel. (After Prantl.)

than one ovule, they are generally arranged along the ventral suture, and the placentation is said to be **marginal** (Figs. 229 and 228, A). In the multilocular syncarpous pistil the ovules are generally arranged in the central axis, where the cells of the ovary meet (Fig. 228, D), and the placentation is **axile.**

When the ovary is unilocular the ovules are arranged either upon the wall (Fig. 228, B), or upon slight projections (Fig. 228, C), and the placentation is **parietal.**

In some cases of a unilocular ovary, as in the Primrose and Pink, the ovules are attached to the end of the flower-stalk which grows up into the ovary (Fig. 230). In this case, which is known as **free central placentation,** the walls of the ovary are perfectly free from the ovules, as can be seen by cutting the pistil of a Pink or Primrose, when the walls can be cut away, leaving the column of ovules in the centre.

The **style,** when present, forms a conducting tube from the stigma to the ovary. In the Violet and Flowering Rush it consists of a perfectly hollow tube; more often, although hollow at first, it becomes afterwards filled up by the growth of **conducting tissue,** so that at the time of fertilisation no channel is evident. As a rule the style grows from the top of the ovary, when it is said to be **terminal.** If it springs out

from the side, as in the Strawberry (Fig. 231), it is **lateral**; if from the base, as in the Alchemilla (Fig. 232), it is **basilar.**

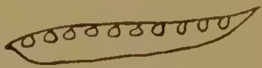

Fig. 229.—Marginal placentation.

Fig. 230. — Unilocular ovary of *Hottonia*, with free central placenta.

Fig. 231.—Lateral style of Strawberry.

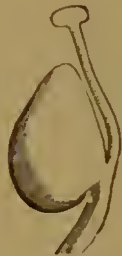

Fig. 232. — Basilar style of *Alchemilla*.

Very often the style is absent, in which case the stigma is said to be **sessile** upon the ovary.

The **stigma** is intended to receive the pollen grains, and hence its presence is necessary in the perfect pistil. It varies much in appearance. In some cases it is merely an opening at the top of the style, upon which is secreted some glutinous fluid. In other cases it is variously enlarged.

Fig. 233.—Petaloid stigmas of *Iris*.

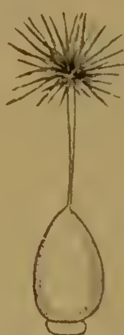

Fig. 234.—Pistil of *Parietaria*, with penicillate stigma.

Fig. 235.—Peltate stigma of Poppy, with hypogynous stamen.

It is **capitate**, or forming a head, in the Primrose and Lily (Fig. 224); **petaloid** in the Iris (Fig. 233); **penicillate**, with a number of hair-like arms, in the Pellitory of the Wall (Fig. 234); **peltate**, or shield-like, in the Poppy (Fig. 235).

When first the macrosporangium begins to form, it appears as a little protuberance of cells. As this grows it forms the main part of the ovule, and is spoken of as the **nucellus.** From its base two integuments arise, the outer, or **primime,** and the inner, or **secundine,** which gradually grow up around the nucellus, leaving, however, at its apex an opening, the **micropyle.**

One of the cells just below the surface at the apex of the nucellus forms the **archesporium.** This, in most cases, divides into two, the upper cell forming the **tapetum.** The lower cell sometimes remains undivided, but in most cases it divides into three or four cells, of which the lowest forms the **embryo sac,** or

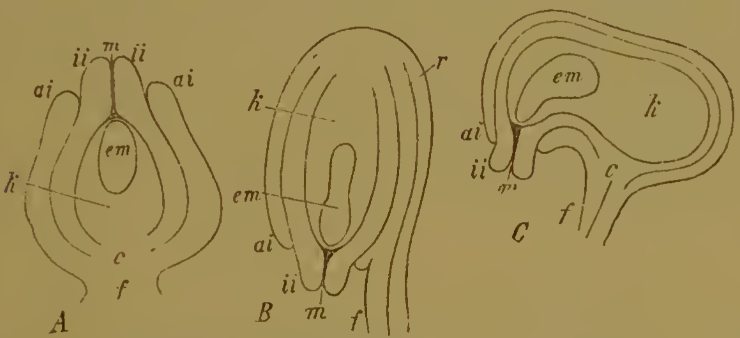

FIG. 236.—Diagrammatic longitudinal sections of ovules: *A*, orthotropous or straight; *B*, anatropous or inverted; and *C*, campylotropous or bent ovule. *ai*, outer integument or primine; *ii*, inner integument or secundine; *m*, the micropyle; *k*, the nucleus, with the embryo-sac, *em*; *c*, the chalaza or base of the nucleus; *f*, the funiculus; *r*, the raphe of the anatropal ovule, formed by the fusion of the outer integument and funiculus. (After Prantl.)

megaspore. Finally, as the megaspore enlarges, the tapetum and the upper cells are disorganised and yield nourishment for the growing embryo sac.

The ovule is generally attached to the placenta by a short stalk, the **funiculus** (*f*), but at other times it is sessile upon the ovary. The point by which the ovule is attached to the funiculus (or placenta) is the **hilum,** whilst the point by which the nucellus is attached to the integuments is the **chalaza** (*c*).

There are three forms of ovules, differing in the arrangement of their parts :—

Orthotropous ovule (Fig. 236, A). In this case the nucleus is straight, the chalaza and hilum are in proximity, and the micropyle is removed to a distance from the funiculus. This form is rare, being met with in the Rhubarb and its allies in the natural order Polygonaceæ.

Anatropous ovule (Fig. 236, B). In this case the nucleus

is straight, but is inverted upon the funiculus, so that the micropyle is brought down into close proximity with the stalk, whilst the hilum and chalaza are separated, being united by a prolongation of the funiculus, known as the **raphe**. This form is well seen in the Dandelion and White Water Lily.

Campylotropous or **bent ovule** (Fig. 236, c). In this case the nucleus is bent, so that whilst the micropyle is brought near the funiculus, as in the anatropous form, the chalaza and hilum are in close proximity as in the orthotropous form, and there is no need of a raphe. The Wallflower and Mallow are examples of this kind. These three forms are united by many modifications.

Thalamus and Disc.—The thalamus, or end of the flower-stalk upon which the various floral organs are inserted, is often specially modified. Thus in all plants with a free central placentation it is prolonged into the ovary, bearing the ovules. In other cases, as in the Umbelliferæ and Geraniaceæ, it is prolonged between the carpels and beyond the ovary, and is known as the **carpophore** (see page 137).

In other cases, as in some forms of Lychnis, Pink, and Passion Flower, it is prolonged beyond the calyx, forming a stalk for the ovary (Fig. 237), and it is known as the **gynophore**. In many plants it is much swollen, and the ovaries are sunk or embedded in it, often giving them a syncarpous appearance when they are truly apocarpous.

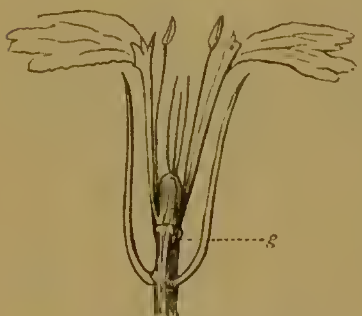

FIG. 237.—Section of *Lychnis Flos-Jovis*, with gynophore, *g*.

We sometimes find between the calyx and pistil a body or bodies which are not universal among flowers, and which cannot be referred to any of the organs above described. To this body the name of **disc** is applied. In the Mignonette and Orange it forms a fleshy swelling below the pistil; in umbelliferous plants it surmounts the ovary, adhering to the styles. In other cases it is variously developed.

Cohesion and Adhesion.—When the similar parts of a flower are united together in growth, we speak of it as **cohesion**: when dissimilar parts are united, as **adhesion**. Thus the formation of a gamosepalous calyx, a gamopetalous corolla, or a monadelphous stamen would be cohesion; whilst the growth of

the calyx to the ovary, or the epipetalous or gynandrous arrangement of stamens, would be due to adhesion.

The general structure and arrangement of the parts can be represented by means of a **floral diagram**, as shown in Figs. 238, 239, and 240. Concentric circles should be drawn to show the position of the floral organs, and on these circles the number of the parts and their cohesion can be shown, together with the æstivation. Thus in Fig. 238 we have a flower with a

FIG. 238.—Floral diagram of the Rose.

FIG. 239.—Floral diagram of Potato (*Solanaceæ*).

FIG. 240. — Floral diagram of Sweet Pea.

polysepalous calyx of five sepals; polypetalous corolla of five petals; numerous free stamens and numerous free carpels. In Fig. 239 the corolla is gamopetalous, and the pistil syncarpous. In Fig. 240 we have an example of diadelphous stamens, nine being shown united and one free. Side by side with the floral diagram, a **floral formula** gives a description, not only of the cohesion, but of the adhesion. In the floral formula the following abbreviations are used: K for calyx, C for corolla, A for andrœcium, G for gynœcium; the number of the parts is shown by figures; ∞ is written for indefinite, *i.e.* more than twelve; brackets ( ), enclosing the numbers, show cohesion; $\frown$, indicates adhesion; a line below the symbol for the gynœcium shows a superior ovary, and above shows an inferior ovary; $\oplus$ for actinomorphic, and $\downarrow$ for zygomorphic flowers. Thus the floral formula for the flowers just referred to would be as follows:—

Fig. 238.—$\oplus$ K5 C5 A ∞ $\underline{\mathrm{G}\ \infty}$.

Fig. 239.—$\oplus$ K5 C(5)A5 $\underline{\mathrm{G}\ 1}$.

Fig. 240.—$\downarrow$ K(5) C5 A(5+4)+1 $\underline{\mathrm{G}\ 1}$.

Fertilisation.—In order that the ovary and ovules may properly perform their function, it is necessary that they should

be fertilised by the pollen. The pollen grain undergoes an important change, usually whilst it is still in the pollen-sac. The nucleus divides, and one of the two daughter nuclei thus formed divides. The undivided daughter nucleus is known as the **vegetative nucleus**; protoplasm becomes aggregated around the two granddaughter nuclei, forming two **generative cells**, which are at present destitute of a cellulose coat, lying free in the protoplasm of the vegetative cell.

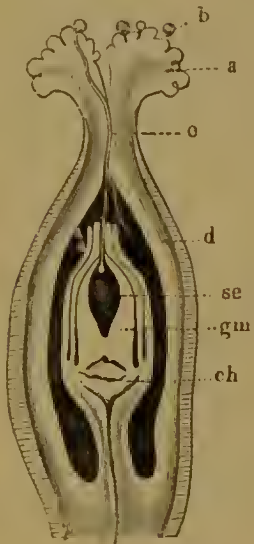

FIG. 241. – Longitudinal section through the uniovular ovary of *Polygonum Convolvulus* at the time of flowering: *a*, stigma; *b*, pollen grains; *c*, pollen-tube; *d*, wall of the ovary; *gm*, the erect orthotropous ovule; *se*, its embryo-sac; *ch*, chalaza: two pollen-tubes have penetrated through the conducting tissue of the style, one of which has entered the micropyle of the ovule, the other not.

By means of which we shall have to speak later on the pollen is carried to the stigma, and is here nourished by the viscid secretion present. At one of the points where the extine is thin it is ruptured, and the intine grows through as the **pollen-tube** (Fig. 242). These tubes grow down the loose conducting tissue of the style and enter the ovary (Fig. 241).

The time necessary for this varies from a few hours to several weeks. In the Crocus it takes from twenty-four to seventy-two hours; in the Arum over five days, and in the Orchids some months. Meanwhile important changes have been taking place in the embryo-sac. The nucleus divides into two, each daughter nucleus passing to the opposite poles of the sac. Each nucleus, again, divides into two, and again a third time, so that there are two groups of four nuclei, one at each pole of the sac. Three of the nuclei at the chalaza end become surrounded with protoplasm and cell walls, forming the **antipodal cells**; three of the nuclei at the micropylar end have protoplasm aggregated around them,

FIG. 242. – Pollen grains putting out their pollen-tube: A, *Dipsacus fullonun*; B, *Cucurbita*.

but without cell walls, and form the **egg apparatus.** Two of these naked cells are known as the **synergidæ**, and the third as

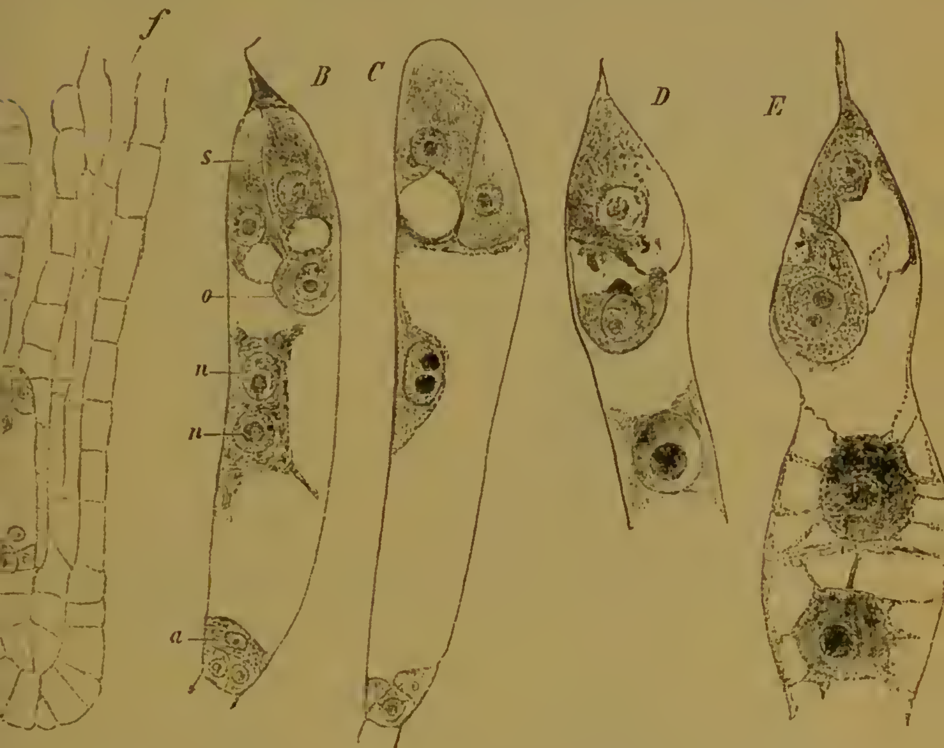

FIG. 243.—*Monotropa hypopitys.* *A*, a mature ovule; *f*, funicle; *i*, integument. *B* and *C*, embryo-sac; *s*, synergidæ; *o*, oosphere; *n*, *n*, formation of secondary nucleus; *a*, antipodal cells. *D* and *E*, upper parts of the embryo-sac. *E* shows the first division for the formation of the endosperm. (Strasburger.)

the **oosphere.** Finally the two remaining nuclei meet together towards the centre of the sac, forming **secondary nucleus.**

As the pollen-tube passes down through the style, the nucleus of the vegetative cell travels down it, followed by the two generative cells. The vegetative nucleus disintegrates, the apex of the pollen-tube becomes applied to the wall of the embryo-sac, the wall of the tube and the sac become absorbed, and one of the generative nuclei, together with the protoplasm, pass into the sac. One

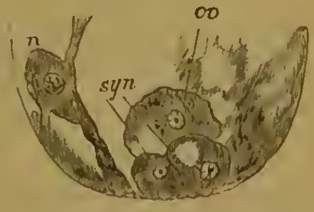

FIG. 244.—Micropylar end of the embryo-sac of *Lamium album* before fertilisation: *oo*, oosphere; *syn*, synergidæ; *n*, secondary nucleus.

fuses with the nucleus of the oosphere. The latter surrounds itself with a cellulose wall, and becomes the fertilised **oospore.** The other generative nucleus fuses with the secondary nucleus. The synergidæ now disappear, and the oospore divides into two cells. The upper one further divides into a string of cells forming the **suspensor**; the lower divides into a mass of tissue from which the **embryo** is formed (Fig. 246). Meanwhile the secondary nucleus divides, forming a large number of daughter

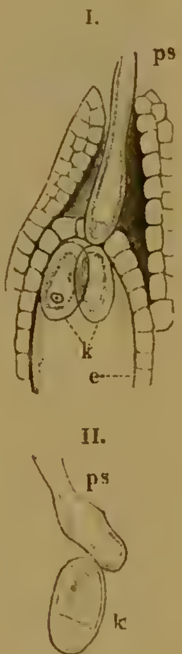

FIG. 245.—Fertilisation of *Canna*. I. Apex of the embryo-sac, *e*, at the time when the pollen-tube, *ps*, has just come into contact with the embryonic vesicle, *k*. II. Fertilised embryonic vesicle separated.

FIG. 246.—Formation of the embryo of *Heliotropium*: *ed*, endosperm; *et*, suspensor; *c*, rudiment of the embryo, its enveloping membrane being already formed; *a*, cells developed out of the two embryonic vesicles.

nuclei, round which cells are formed, filling the embryo-sac. These cells are filled with nutritive material of various kinds, and form the **endosperm**, which is stored for the nourishment of the embryo (Fig. 248). Sometimes nutritive cells are produced within the nucellus outside the embryo-sac. In this case, the term **perisperm** is applied.

Thus the ovule is converted into the seed. Very often as the embryo increases in size the nutritive cells around are absorbed, until, as we have seen in the case with the Broad Bean,

the young plant occupies the whole of the nucellus. In other cases a part of the endosperm, or of the perisperm, or of both, persists, forming the so-called **albumen.**

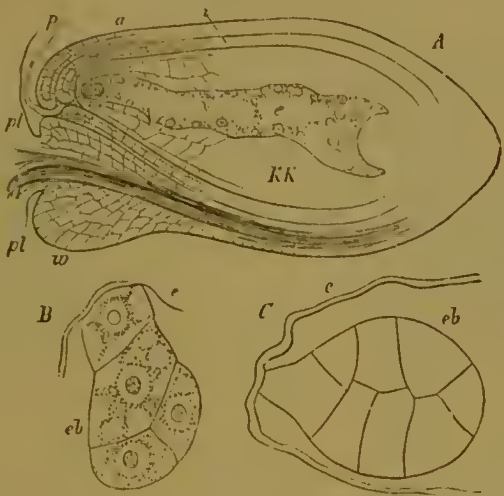

FIG. 247.—*Viola tricolor.* *A*, longitudinal section of anatropous ovule after fertilisation: *pl*, placenta; *w*, swelling on the raphe; *a*, outer, *i*, inner integument; *p*, pollen-tube entering micropyle; *e*, embryo-sac, with the fertilised germinal vesicle at the micropyle end, and numerous endosperm cells at the other. *B*, apex of embryo-sac, *e*, with young embryo, *eb*, of three cells, and one cell forming the suspensor or pro-embryo. *C*, same, further advanced. (After Sachs.)

In the fertilisation of Fir trees and their allies there is a modification of this process. Before the pollen grains leave the anthers, two or more small **prothallus cells** are cut off from one end of the grain. Then there is formed one **antheridial cell** within the pollen grain which further contains a vegetative nucleus as well.

FIG. 248.—*Viola tricolor.* Posterior part of embryo-sac; *c*, wall; *S*, cavity of the cell; *K*, *K*, young endosperm cells formed by free cell formation in the protoplasm, *pr*. (After Sachs.)

The ovules, instead of being enclosed in an ovary, are naked (whence the plants are said to be **gymnosperms,** or naked, seeded plants, whilst other flowering plants are **angiosperms,** or enclosed seeded plants), and they have but one integument, the pollen falling direct upon the micropyle (Fig. 250). In the **megaspore,** or embryo-sac, by free cell formation, a number of cells are formed, filling up the whole of the sac. This is known as the

endosperm or female **prothallus.** At its upper or micropylar end there are formed two or three **archegonia.** Each archegonium is produced in the following manner. A single superficial cell divides into two; the upper dividing produces the **neck,**

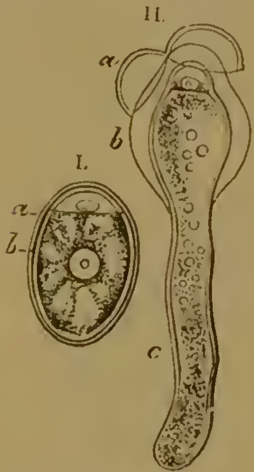

FIG. 249.—Fertilisation of *Cupressus sempervirens* (Coniferæ). I. A pollen grain with its two cells: *a*, extine; *b*, intine. II. Pollen grain in which the pollen-tube, *c*, has been formed.

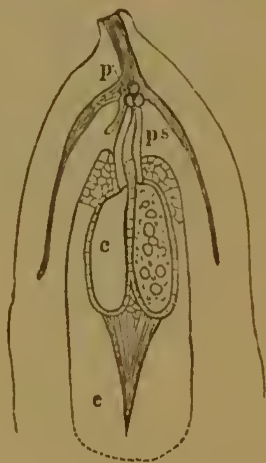

FIG. 250.—Fertilisation of *Abies excelsa*: *p*, pollen grains; *ps*, pollen-tubes; *c*, two corpuscules in the embryo-sac, *e*.

whilst the lower one is enlarged and forms the **venter.** Just before the entrance of the pollen-tube the venter divides; a small portion which is cut off from the upper part forms the **ventral canal cell,** whilst the large lower part is the **oosphere.**

The process of fertilisation takes two years to complete. In the first year the pollen-tube grows for a short distance, and then its further development is arrested. In the second year, usually about April, the development of the tube recommences; the antheridial cell divides into two, a **stalk cell** and two **generative cells;** the nucleus of one generative cell fuses with the nucleus of the oosphere, fertilising it and producing the **oospore.** The formation of the embryo from the fertilised oospore differs very much from the same process in angiosperms. The nucleus divides into two and then into four, so that four nuclei are

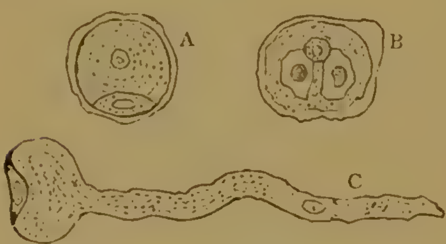

FIG. 251.—Pollen of Tulip, A, B; and of Flowering Rush, C.

produced at the base of the oospore. These divide again to form eight, and yet again to form sixteen, so that finally there are four rows of nuclei, four in each row, all placed towards the base of the cell. The four uppermost nuclei remain free in the cell; the other twelve, with their protoplasm, become surrounded by cell walls. The upper four cells thus formed remain as they were; the second four elongate, forming the **suspensors**, separating from one another as they do so; finally the four basal cells at the end of the suspensors divide to produce each of them an **embryo**. There is thus the possibility of four embryos being formed in each archegonium—but, as a rule, only one of the four is developed.

As a general rule the pollen does not fertilise the ovules of the *same* flower, but is taken to another, and the process known as **cross-fertilisation** is brought about. The pollen is carried from flower to flower by various means. The first agency we shall notice is the wind. In the Hazel, for example, we have a monœcious plant with unisexual flowers. It is evident that the pollen must be transferred from one flower to another. The male and female catkins are on the same plant (Fig. 162), the former pendulous with numerous anthers and a large quantity of pollen, the latter erect with the red stigmas appearing through the enveloping bracts. When the pollen is fully ripe it is shed from the anther cells and scattered by the wind; the greater portion is wasted, but some falls upon the stigmas, fertilising them. Such a plant is said to be **anemophilous**, or wind-fertilised. Other examples of anemophilous plants are to be found in the Oak, the Fir, the Yew, and various Grasses and Cereals. In all these cases the flowers are small and inconspicuous and destitute of odour, whilst the pollen is produced in a far larger quantity than is actually needed for fertilising purposes. Often in Fir forests the pollen is given off into the air in such enormous quantities that it is washed down by the rain as a yellow powder, and is popularly known as *sulphur rain*.

More important agents in the fertilisation of flowers are insects. In all cases of insect-fertilised (**entomophilous**) plants the flowers possess either rich and variegated colours, or sweet odours, or have both qualities. These serve to attract the insect, whilst in some part of the flower honey is stored up in a nectary. Whilst endeavouring to obtain this the insect comes into contact with the anther, and the pollen is scattered over portions of its body, and being carried away, adheres to the glutinous stigma of the next flower visited.

The mechanical contrivances and arrangements to ensure this proper distribution of the pollen are very numerous. In an elementary book such as this it is only possible to notice a few typical forms.

In many cases it is impossible for the flowers to be self-fertilised, as either the anthers are ripened before the stigmas, or the stigmas before the anthers. This is known as **dichogamy**, and in the former case the flower is **protandrous**, and the pollen has to fertilise the pistil of a flower which preceded it in opening; whilst in the latter case the flowers are **protogynous**, and the pollen fertilises a later flower.

A good example of a protandrous plant, and one which at the same time shows mechanical arrangements for ensuring the delivery of the pollen upon the right part of the insect's body, is to be found in the Sage. Fig. 252 shows in diagrammatic form the arrangement of the parts in *Salvia officinalis*. The corolla is bilabiate, the lower lip forming a convenient resting-place for the insect to stand upon, whilst the upper lip protects the stamens and pistil from the rain.

The stamens, two in number, have branched connectives; the lower lobes are abortive and united together (*b*), so that if either be pushed it affects both stamens. The upper lobe is full of pollen, and is poised upon the movable connective in such a manner that if the abortive lobes are pushed backwards and upwards the upper ones come downwards and forwards. In the corolla tube

FIG. 252.—Sage fertilisation.

honey is secreted. The style and stigmas at first are placed well back against the upper lip, and are not matured until after the pollen. When they are matured, however, the style

bends forward (*d*), bringing the stigmas near the centre of the mouth. If a bee visits one of the flowers which has its pollen matured, in order to seek for honey, it will, on entering the flower and plunging its proboscis into the tube, strike its head against the lower anther lobes, bringing the fertile lobes down against its sides, covering its body with pollen (*c*).

If it now visits another flower in the same condition, it will simply have its stock of pollen increased; but if it visits a flower which has its pistil bent over, evidently the stigmas will strike against the insect's back, and some of the pollen scattered there will adhere to the glutinous stigmatic surface.

Other protandrous flowers are met with in the Mallows, the Geraniums, many Campanulas, the Pinks and other members of the Caryophyllaceæ, many Compositæ, Umbelliferæ, and others.

Protogynous flowers are much less common, but they are met with amongst the Plantains, the Scrophularias, the Magnolias, and other species of plants.

Another arrangement is known under the name of **heterostylism**, where the pistils and stamens of different flowers are of various lengths. A good example of a heterostylic flower is to be found in the common Primrose. If we examine a bunch of common Primroses we shall find the flowers of two different kinds. Some have a little knob filling up the mouth of the corolla tube, and others a rosette. On making a vertical section of one of each kind of flower, we find the arrangement as shown in Fig. 253. In the first case we have the pistil with a long style (253, I.), the stigma of which forms the "knob" filling up the corolla tube, whilst the stamens are placed low down in the tube. In the other case the stamens are high up, forming the "rosette" (253, II.), whilst the style is short and the stigma at about the same height as the stamens in the preceding variety. Such a flower is said to be **dimorphic**, and we can speak of the "long-styled" and "short-styled" varieties of Primrose. There is a slight difference in the pollen and the stigmas in the two cases. The pollen grains of the short-styled flowers are larger than those of the long-styled flowers, and the stigma in the latter case is globular, whilst in the former it is

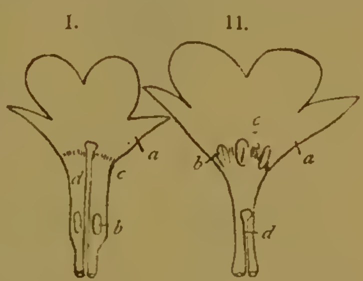

FIG. 253.—Dimorphic flower of *Primula*. I. Long-styled, II. Short-styled form; *a*, corolla; *b*, anthers; *c*, ring of hairs; *d*, pistil.

depressed in the centre. A number of careful experiments by Professor Darwin and others show that long-styled flowers are fertilised by the pollen from short-styled, and *vice versâ* the short-styled are fertilised by the pollen from the long-styled. Such a cross Mr. Darwin calls *legitimate union*, whilst the term *illegitimate union* is applied to the union of long-styled pollen with long-styled stigma. This illegitimate union will not produce seeds to the extent that the legitimate will, and in some dimorphic flowers none at all are formed.

In some species of Lythrum we have **trimorphic** flowers: one with long style, six medium stamens, and six short stamens;

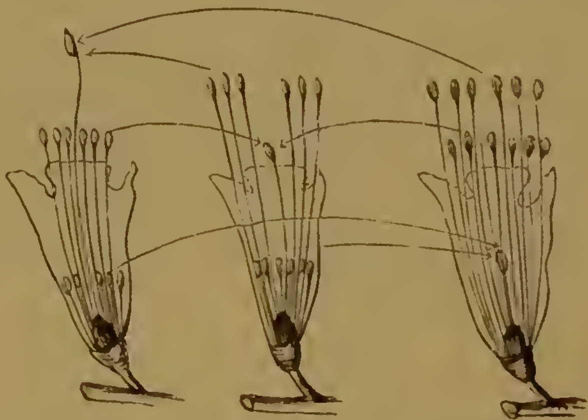

FIG. 254.—Trimorphic forms of *Lythrum*.

one with medium style, six long stamens, and six short stamens; and one with short style, six long stamens, and six medium stamens. In such cases we always find that the long style is fertilised by the long stamens, the medium style by the medium stamens, and the short style by the short stamens, as shown by the lines in the diagram.

Whilst these provisions for cross-fertilisation are the rule amongst flowers, in some few cases there is a special arrangement for self-fertilisation. The Sweet Violet is a good example. The well-known flowers that appear in the spring do not, although fertilised by insects, bear fruit. They are followed in the summer by small inconspicuous apetalous flowers, where the stamens and pistil are enclosed in a calyx which does not open. The result is, the flowers are fertilised by their own stamens. Such flowers are said to be **cleistogamous**. Besides this there are other examples where self-fertilisation is specially provided for.

RELATION OF FLOWER TO OTHER PARTS OF THE PLANT.

The parts of the flower must be looked upon as modified foliar organs. This is pretty evident in the calyx and corolla, but not so well seen at first in the stamens. We have proof, however, in the facts, 1st, of the tendency in double flowers to form petals instead of stamens; and 2nd, the gradual transition from petals to stamens, as seen in the white Water Lily, or *Rosa centifolia* (Fig. 255).

In some cases the filament appears to represent the petiole,

FIG. 255.—Stages of transition between the petals and stamens of *Rosa centifolia.*

the connective the midrib, and the anther the blade, bearing pollen cavities or **sporangia** upon it.

We must regard the carpels as leaves (carpellary leaves), either folded over so that their edges meet, when the dorsal suture marks the midrib, and the ventral the margin of the leaves, or, in a unilocular polycarpellary pistil, the carpellary leaves unite by their margins. The placenta is developed on the margin of the carpellary leaves, or in the free central placentation on the prolongation of the stem. The ovules are sporangia borne upon the carpellary leaves, or, in the case of the free central placentation, upon the prolonged axis.

CHAPTER XI.

FRUIT AND SEED.

AFTER fertilisation a change takes place in the ovary; it enlarges and changes very much in appearance, forming the fruit. Botanically the **fruit** is the **ripened ovary**. Many so-called fruits, however, have in addition to the ovary some other part of the flower attached. Thus, in the Strawberry and Apple, the fleshy edible part is the enlarged receptacle or thalamus, the pips of the Strawberry and the core of the Apple being the true fruits. In these cases the term **pseudocarp** is applied. Sometimes the whole inflorescence will be matured into a single fruit-like mass, when the term **syncarp** is used: whilst if the bracts or any other part of the floral organs are added in so as to produce a pseudocarp, as in the Pineapple and Mulberry, the term **pseudosyncarp** is employed (Fig. 256).

FIG. 256.—Multiple pseudocarp of the Mulberry.

(Care must be taken not to confound the terms *syncarp* and *syncarpous* pistil or fruit; the latter term being, as we have seen, restricted to those ovaries and fruits where the carpels are united together, whilst the former term is used for matured inflorescences even if the pistil be apocarpous.)

The walls of the ovary consist of three layers: hence in the fruit we find three layers present—the outer or **epicarp**, the middle or **mesocarp**, and the inner or **endocarp**. Often these three layers cannot easily be distinguished from one another; at other times they are very evident. The number of cavities or loculi in the fruit generally corresponds to that in the ovary: sometimes, however, some of the partitions disappear, so that the fruit possesses fewer loculi than the ovary.

We may divide fruits into those which are **dehiscent** or break, and those which are **indehiscent** or do not break, when ripe.

DEHISCENT FRUITS.

When a dehiscent fruit opens so that the seeds fall out, it is known as a **capsule**. The dehiscence may take place longitudinally or from top to bottom of the fruit, breaking it into several valves; it is then said to be *valvular*. Or it may take

FIG. 257.—Capsule of *Primula* dehiscing by ten teeth.

FIG. 258.—Capsule or pyxis of *Anagallis*, with circumscissile dehiscence.

FIG. 259. Capsule of Poppy dehiscing by pores beneath the peltate stigma.

place in a transverse manner, opening off like a lid, when it is described as *transverse* or *circumscissile* dehiscence (Fig. 258). Or, lastly, there may be small openings or pores, when the dehiscence is *porous* (Fig. 259).

If the longitudinal dehiscence is partial, so as to only take

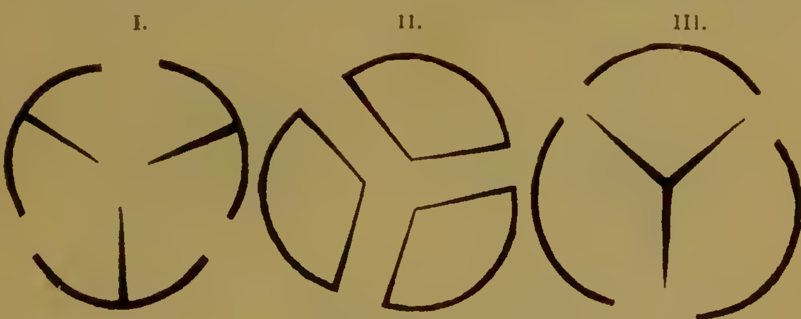

FIG. 260.—I. Diagram of a loculicidal capsule. II. Diagram of a septicidal capsule III. Diagram of a septifragal capsule.

place at the top of the fruit by means of a number of teeth, it is *dehiscent by teeth* (Fig. 257).

If the dehiscence is complete, it may either take place by the ventral suture, or by the dorsal suture, or by both. Again, in some cases the walls of the loculi split open, leaving the septa attached to them, as in the Lily and Iris; the dehiscence is then said to be *loculicidal*. It is *septicidal* when the fruit breaks up into its separate carpels, the dehiscence taking place

down the septa themselves, as in the Rhododendron and Colchicum; and it is *septifragal* when, the carpels opening by their dorsal sutures, the dissepiments separate from the valves,

FIG. 261.—Septifragal capsule of *Datura*.

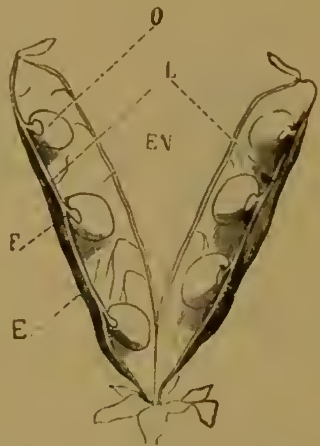

FIG. 263.—Legume of Pea split lengthwise: E outer, EN inner layer of the pericarp; L, placenta; F, funiculus; O, seed.

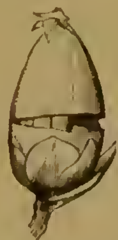

FIG. 262.—Capsule or pyxis of *Plantago*, with circumscissile dehiscence.

FIG. 264.—Fruit of *Illicium* or Star-Anise, consisting of a number of follicles.

being still attached in the centre, as in the Thorn-apple (see Figs. 260 and 261).

Some forms of capsules have received special names. A **pyxis** is a capsule dehiscing transversely, as in the Anagallis (Fig. 258) and Plantago (Fig. 262).

A **legume**, or pod, is a unilocular monocarpellary capsule dehiscing by both dorsal and ventral sutures, as in the Pea (Fig. 263).

A **follicle** is a monocarpellary capsule dehiscing by ventral

suture (Figs 264 and 265), or, in some Magnolias, by dorsal suture, only.

A **siliqua** is a syncarpous bicarpellary capsule, one-celled, with a false division or **replum** running up the centre. It is long and narrow in shape, and the two side walls break away, leaving the central replum with the seeds. An example is seen in the fruit of the Wallflower (Fig. 266).

FIG. 265.—Fruit of Peony, consisting of two follicles.

A **silicula** resembles the last, except that, instead of being long and narrow, it is short and broad (Fig. 267).

When a dehiscent fruit breaks up into several portions which are usually one-seeded and remain closed, although they do in some few cases open to allow the seeds to fall out, it is called a **schizocarp**, the divisions being called mericarps.

There are also several varieties of schizocarp.

FIG. 266.—Wallflower (*Cheiranthus Cheiri*). Siliqua.

FIG. 267.—Silicula of *Cochlearia*, open and showing the seeds attached to the replum.

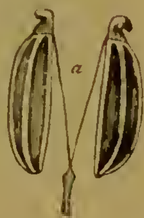

FIG. 268.—Cremocarp of the Fennel: *a*, carpophore.

A **cremocarp** is a bicarpellary schizocarp dehiscing into two mericarps attached to a central carpophore. Examples are found in the Fennel (Fig. 268) and the other members of the order of Umbelliferæ.

A **samara** is a winged fruit: in some cases, as in the Maple (Fig. 269), it is a schizocarp breaking up into two one-seeded portions; in other cases, as in the Birch (Fig. 270), it is an indehiscent fruit.

A **lomentum** is a schizocarp dehiscing transversely into two

Fig. 209.—Bipartite schizocarp of the Maple, consisting of two samaræ.

Fig. 272.—Quadripartite schizocarp of *Ajuga*, consisting of four nucules.

Fig. 273.—Tripartite schizocarp of *Tropæolum*.

Fig. 270.—Bract of the Birch (*Betula*), with three samaræ in its axis.

Fig. 271.—Lomentum of *Hedysarum*.

Fig. 274. Quinquepartite schizocarp of *Geranium Robertianum*. I. The immature pistil. II. The mature fruit.

or more one-seeded mericarps, as in the Hedysarum (Fig. 271) and Radish.

A **carcerulus** is a quadripartite schizocarp, as seen in the Bugle (Fig. 272) and other labiate plants. Each of the four divisions is often called a **nucule**. In other cases the schizocarp may be *tripartite* (divided into three mericarps) as in the Indian Cress (Fig. 273), *quinquepartite* (five mericarps) as in the Geranium (Fig. 274), or *multipartite* (many mericarps) as in the Mallow (Fig. 275).

Fig. 275.—Multiparite schizocarp of *Malva*.

INDEHISCENT FRUITS.

The **drupe,** or **stone fruit.** In this case the three layers of the fruit are always distinct. The endocarp is hard, forming the so-called stone. The epicarp and mesocarp differ in their consistency. In the Plum, Cherry, and Peach (Fig. 276) the epicarp forms the skin, and the mesocarp the succulent edible portion. In the Cocoanut (Fig. 277) both epicarp and meso-

FIG. 276.—I. Longitudinal section through the unilocular drupe of the Peach. II. Through the bilocular drupe of *Cornus*.

FIG. 277.—Longitudinal section of Cocoanut: *a*, epicarp; *b*, endocarp; *c*, testa; *d*, endosperm or albumen; *e*, embryo; *f*, cavity in the endosperm which contains the milk.

carp are dry and fibrous, whilst in the Almond and Walnut they are leathery. In some few cases, as in the Cornel (Fig. 276, II.), there are two loculi in the drupe, usually there is but one.

The **berry,** as seen in the Gooseberry (Fig. 278), Grape, or Currant, has the endocarp soft and succulent as well as the mesocarp, whilst the epicarp forms a skin. In the Gourd and Cucumber we have a fruit much resembling the true berry, but the outer layers are firmer and harder; such a variety of berry is known as a **pepo.** The fruit of the Orange, known as a **hesperidium,** is a multilocular berry; whilst in the Apple we have a berry-like pseudocarp, the fleshy edible portion being the enlarged thalamus, and the scales above forming the

remains of the calyx, whilst the core is the true fruit. This variety is known as a **pome**.

In the **achene** (Fig. 280) all three layers of the fruit are

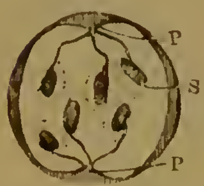

FIG. 278.—Transverse section through a Gooseberry; the firmer outer layer of the pericarp encloses the succulent flesh; the seeds lie imbedded in the latter, and are attached by long funiculi to two opposite parietal placentæ.

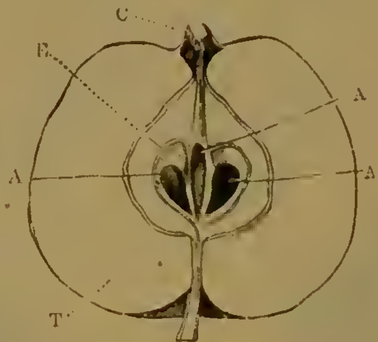

FIG. 279.—Longitudinal section through an Apple; C, dry persistent calyx limb; E, loculi with cartilaginous pericarp; T, mesocarp.

FIG. 280.—Achene.

FIG. 281.—I. Acorn of *Quercus sessiliflora*, with two empty cupules. II. Longitudinal section through the fertilised pistillate flower, with the cupule in an early state.

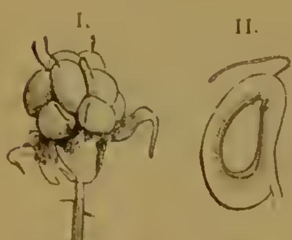

FIG. 282.—Fruit of Dewberry (*Rubus cæsius*). I. Natural size. II. A single drupel.

FIG. 283. Pseudocarp of the Strawberry.

FIG. 284.—Section of fruit of Rose.

dry; whilst if they are lignified, as in the Nut and Acorn (Fig. 281), the term **glans** is employed.

Sometimes we have several fruits produced from the ripening of the apocarpous pistil of a single flower, and the name of **etærio** is applied.

Thus in the Raspberry, Blackberry, and Dewberry (Fig. 282) we have an etærio of drupes. In the Buttercup and Strawberry we have an etærio of achenes (in the latter case, as we have seen, the edible portion is the enlarged thalamus).

In the Rose (Fig. 284) we have an etærio of achenes contained within a hollow receptacle, and the whole pseudocarp is called a **cynarrhodum.**

THE SEED.

We have already, in Chapter II., described the seed in a general manner; there are, however, a few details which it is necessary to note at this point. Various terms are used to describe the arrangement of the radicle and cotyledons in the embryo. When the two cotyledons lie flat upon one another, and the radicle is placed upon the line which separates them, as is the case with many cruciferous plants (Fig. 285), the embryo is **pleurorhizal.**

I.

II.

FIG. 285.—Pleurorhizal embryo of *Lunaria*. I. Transverse, II. Longitudinal section through the seed.

When the cotyledons are flat upon one another, but the radicle is placed upon the back of one of them (Fig. 286), the embryo is **notorhizal.**

When the two cotyledons are folded upon one another leaving a hollow channel in which the radicle is placed (Fig. 287), the embryo is **orthoplozic.** When, lastly, the flat cotyledons are spirally coiled (Fig. 288), the embryo is **spiral.**

Again, in albuminous seeds, if the embryo is in the centre surrounded by the endosperm, as in the Pansy (Fig. 289), the former is said to be **central,** and the latter **peripheric.**

The case is just reversed in the *Mirabilis Jalapa* (Fig. 290), where the **peripheric** embryo is bent round the **central** endosperm.

At other times the embryo and albumen are placed more side by side, when they are said to be **lateral.**

In some plants a peculiar appendage is developed from the hilum of the ovule after fertilisation, and, growing up round the

I. II. III.

Fig. 286.—Seed of *Neslea paniculata.* I. Entire. II., III. Sections in two different directions, showing the notorhizal embryo.

I. II. III.

Fig. 287.—Seed of *Eruca sativa.* I. Entire. II., III. Sections in two different directions, showing the orthoplozic embryo.

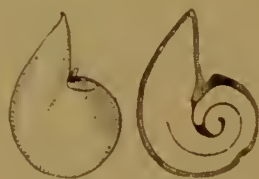

Fig. 288.—Spiral embryo of *Bunias Erucago.*

Fig. 289. — Peripheric endosperm surrounding the central embryo in the Pansy.

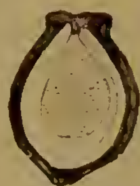

Fig. 290.—Peripheric embryo surrounding the central endosperm in *Mirabilis Jalapa.*

Fig. 291.—Lateral embryo of *Menispermum canadense.*

seed, forms either a complete coat as in the Yew (Fig. 292), a perforated coat as in the "mace" of the Nutmeg, or hairs as in the case of the Willow. This is known as the **arillus.**

Dispersion of Seeds.—Plants being fixed in the soil, were there not some means of scattering their seeds, the offspring would crowd around the parents and thus choke them. In some cases, where the fruits are dehiscent, it is the seeds

themselves which are dispersed; the fruits are scattered when they are indehiscent.

The chief agents which assist in the dispersal are the wind,

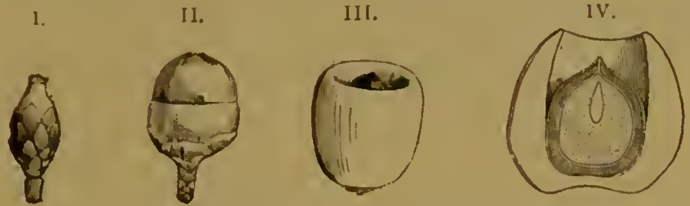

FIG. 292.—I., II., III. Development of the arillus of the Yew. IV. Longitudinal section through the ripe seed.

animals, moving water, and some mechanical contrivances in the ripening fruit.

The wind: The chief adaptations for distribution by the wind are:—

	Seeds dispersed. Fruit dehiscent.	Fruit indehiscent and dispersed.
a. Small size and lightness.	Heaths and Orchids.	Nutlets of many Labiatæ.
b. Flattened form.	Wallflower.	Mericarps of many Umbellifers.
c. Wings.	Pine (no true fruit)—Gladiolus.	Samaræ, *i.e.* Elm, Birch, Sycamore, Maple, Hornbeam.
d. Haired tails.		Anemone, Clematis.
e. Tufts of Hairs.	Willow, Poplar, Willow Herb—Cotton Plant.	Pappus of many Compositæ.

Animals assist in two ways.

a. By transporting seeds and fruit which attach themselves to their skin or limbs by means of hooked spines. Examples, Burdock, Wood Sanicle, Cleavers, etc.

b. By eating the juicy fruits and dropping the hard stony seeds which are not injured by the digestive juices. Examples, Various Berries, Drupes, etc.

Rivers and *ocean currents* transport the seeds of water and other plants, which are mostly adapted to floating on water. Examples, Water Lily, Cocoanut, and some sedges.

Mechanical arrangements.—In many cases the fruits burst and scatter the seeds often to a considerable distance from the plant. Examples are to be found in the garden Balsam and the Wood Sorrel.

CHAPTER XII.

THE MOVEMENT OF WATER IN THE PLANT TISSUES.

In the tissues of a living plant there is a continual movement of water, the amount of movement being governed by various circumstances. This movement may be readily described under three heads.

1. **Slow Movement.**—Wherever cells are growing water is needed to aid their growth. Again, during the process of assimilation, water is the chief source of the hydrogen which is required for the formation of the organic materials. Also water is needed in the reservoirs where the assimilated food is stored up in order to re-dissolve that food and convey it to the growing parts. All of these necessities cause a flow of water towards these parts. This flow, like the growth and assimilation, is slow. It is caused by osmosis, the growing cell absorbing water from the next, and so on till the source of water is reached. It takes place in the parenchyma and meristem of the stem. It is greatest during the spring and early summer—the time of most rapid growth.

2. **Rapid Movement.**—In plants which grow entirely under water the slow movement is the only one which exists. In all ordinary plants there is, however, another kind of movement going on due to the transpiration which we have seen takes place in the leaves. As water thus escapes a fresh supply has to be obtained, and this passes up entirely through the lignified cells of the xylem. If the supply is not sufficient to replace the loss, the leaves droop and wither. This is the reason why a branch cut from a tree so soon withers, as there is no water to compensate for evaporation. If such a branch is placed in water it cannot, as a rule, obtain a sufficiency of the needed liquid, owing to the fact that cutting the stem in the air acts

upon the cut surface in such a way as to diminish its absorbing power. If, however, the stem is cut under water, absorption takes place as usual. That the current does take place through the wood can be shown—(1) If a ring of bark is cut off the stem of a growing plant, as long as the wood is uninjured the leaves will not droop; and (2) if the plant is watered with some coloured solution it is found to rise in the wood, staining it. The amount of the flow of water in the wood depends upon the amount of transpiration. It is greatest in the summer, when the transpiration is most rapid. There is no doubt but that the water passes mainly through the *cavities* of the vessels and tracheids. The maintenance of the transpiration-current is not, however, quite satisfactorily explained. It appears to depend chiefly upon two conditions, *viz.* the evaporation going on at the surface of the leaves and other parts of the plant, and also on certain physical properties of the columns of water in the plant. These can only be broken with difficulty, and as long as the protoplasmic substance of the leaf and stem parenchyma is living, such a rupture does not ordinarily occur.

FIG. 293.—Apparatus for measuring root-pressure.

Trees can be much more readily transplanted in the late autumn and winter than in the summer, because at the former times the plant is not losing so much water by transpiration, and so it matters less that when they are transplanted at first the roots do not take up much water.

3. **Root-pressure.**—We may regard both of the movements of water of which we have been speaking as due to suction. There is, however, a third movement which is due to root-pressure, and which depends neither upon growth nor evaporation. If the stem of a plant is cut, and the surface is protected

from evaporation, water is found to ooze out. This is caused by the pressure of the root. The amount can be measured by means of a manometer (Fig. 293). Sometimes this root-pressure causes an exudation of water in various parts of plants. Examples are to be seen in many Grasses, Aroids, and Alchemilla, where the water escapes in drops along the margins and at the tip of the leaves.

It is especially in spring that this root-pressure is noticeable. In summer, when active transpiration is going on, it is reduced to a minimum.

CHAPTER XIII.

INFLUENCE OF HEAT AND LIGHT UPON GROWTH.

THE various vital phenomena can only be carried on within a certain range of temperature. There is a minimum below which and a maximum above which the activity ceases. The maximum and minimum vary with different plants and for the different processes of the same plant. Roughly speaking, however, from 0° C. to 50° C. may be looked upon as the range. Between the maximum and minimum there is always a temperature, the optimum, at which the vital function is most active.

Thus, taking the germination of Maize, 9·5° C. is the lowest temperature at which it is possible; as the temperature is increased the Maize germinates more readily until the optimum is reached at 33·7° C. Beyond this the germination is less and less active until the maximum is reached at 46·2° C.

Comparing Wheat with this, we find that the minimum of germination is 5° C., the optimum 28·7° C., and the maximum 37·7° C.

The injurious action of high and low temperatures upon plants depends to a great extent upon the amount of water present. Dry peas do not lose their power of germination even if exposed to a temperature of 70° C. for an hour, whilst if wet a temperature of 54° C. will kill them. In the case of low temperatures the injury is due to the water being separated from the protoplasm. It never freezes within the cell, but is separated and forms crystals of ice outside the cell wall. These crystals often considerably injure the tissues. If afterwards the thawing is gradual the tissues may recover, but if it is too rapid the water cannot be reabsorbed, and either rotting ensues, or the water evaporates and the plant dries up.

A curious effect of cold upon some plants is to change the

colour of the chlorophyll. Thus the leaves of Yew, Pine, Juniper, Box, and other plants turn red or reddish brown under the influence of cold.

Light also plays an important part in the life and growth of plants. We may divide the effects of light under two heads.

1. **Chemical Action of Light.**—This is seen in the formation of chlorophyll and in the decomposition of the carbon dioxide of the atmosphere, the assimilation of carbon, and the production of starch and other organic compounds. These changes can only take place in the light. A plant grown in perfect darkness will, as we have seen, be etiolated, and no starch will be formed. A very slight amount of light—the diffused light at the back of a room—will be sufficient to produce the green colour; but for the production of starch much brighter light is necessary. Metastasis, that is, the conversion of one kind of organic material into another (such, for instance, as the conversion of starch into sugar during the germination of many seeds), can go on without the aid of light. A plant that contains a large reservoir of food material will grow, nay even produce flowers and fruit, in the dark; losing, however, instead of increasing in weight. The growth of tubers and bulbs in the dark and the germination of seeds are cases in point.

2. **The Mechanical Action of Light.**—Upon the development of the internodes of growing shoots light exerts a retarding influence. If a plant, such as a Broad Bean, is grown in darkness, it is found that not only does it present an etiolated appearance, but that the internodes are much longer than those of a corresponding plant grown in the light.

Again, if a plant is grown in a window, so that the sunlight falls upon only one side of it, very soon the stem will be found to bend over to the window. Such a bending is known as **heliotropism.** It is produced by the retarding influence of the light upon that side of the plant which is turned towards it. In some few cases the bending is in exactly the opposite direction. When the bending is towards the light it is called positive, and when away from it, negative, heliotropism.

The mechanical and chemical actions of light are brought about by different series of rays. The least refrangible, those towards the red end of the spectrum, have the greatest chemical effect; the most refrangible, those towards the blue end of the spectrum, possess the greatest retarding influence.

Sachs gives the following table as the result of his experiments upon the amount of carbon dioxide decomposed by the

various rays of the spectrum (that decomposed by the yellow being reckoned 100):—

Red	25·4
Orange	63·0
Yellow	100·0
Green	37·2
Blue	22·1
Indigo	13·5
Violet	7·1

If plants are grown surrounded by glass vessels, in the one case filled with a solution of potassium bichromate, which only allows red, orange, and yellow rays to pass through, and in the other case with a solution of ammoniacal copper oxide, which only allows green, blue, and violet rays to pass, in the former case no bending takes place, whilst in the latter case the heliotropism is as great as in the light.

CHAPTER XIV.

IRRITABILITY OF PLANTS.

Not only is there a movement of plants or parts of plants during growth, but also certain fully formed organs of plants are motile, especially under the influence of an external stimulant. One of the best known examples is the Sensitive Plant (*Mimosa pudica*) (Fig. 298). The leaves of this remarkable plant are bipinnate, and are articulated to the stem. The four pinnæ and the separate leaflets are also articulated. Spontaneously at evening, or under the influence of any irritant, the leaflets fold upwards, whilst the leaf-stalk as a whole bends downwards. The movement is due to the presence at the base of the stalk and of each leaflet of a mass of succulent parenchyma—the pulvinus. The cells are saturated with water, rendering them turgid. On irritation some of the water escapes into the intercellular spaces, and the elastic cell walls contract, producing the movement. When the irritation is removed the sap is drawn again into the cells, causing the return of the leaf to its normal position.

The movement only takes place between the temperatures of 15° C. and 40° C. Oxygen appears to be necessary, as under the exhausted receiver of an air-pump, or in an atmosphere of hydrogen, nitrogen, or carbonic acid, the leaves of *Mimosa* cease to move. Anæsthetics, as chloroform, also cause a cessation of the movements.

The leaves and leaf-hairs of Venus's Fly-trap (Fig. 143) and Sundew are irritable. When a fly alights upon the surface of the leaf it causes a bending over of the sides of the leaf to enclose it.

The stamens of many flowers are irritable. The Barberry is a good example. There are six stamens surrounding the pistil. If one is touched it springs forward towards the ovary.

At the base of the stamens are honey glands; insects visiting the flowers in search of honey strike against the stamens, causing them to fall forward, scattering the pollen over the intruders' bodies.

In the *Centaurea* and some other Compositæ the stamens contract on touching. Some leaves, although they are not sensitive to touch, close at the approach of night. The leaflets of Wood Sorrel fold down, those of Clover fold up. Changes of temperature and variation in the amount of light produce these movements.

The opening and closing of flowers at certain hours of the day is a phenomenon due to similar causes.

CHAPTER XV.

CLASSIFICATION.

UNDER the head of Classification we include the grouping of plants into classes according to their affinities. There are two great systems of classification, the *Artificial*, or (as it is often called) the Linnæan, and the *Natural*. In the former case the plants are arranged simply according to the number, position, and relation of their stamens and carpels; in the second case the general structure and arrangement of the plant as a whole is taken into account. The result is that although the Artificial system is a most useful one for the purpose of tracing out a flower whose name we may wish to discover, yet since it depends solely on the arrangement of one set of organs, it often separates plants which are evidently closely allied, and on the other hand unites those which possess no common properties beyond the structure of their flowers. For these reasons, for the purposes of classification, the Natural system is now always employed.

The sub-kingdom of Flowering Plants is divided into two classes, the **Dicotyledons** and **Monocotyledons**, most of the distinctive characteristics of which we have already noted, and hence it will only now be necessary to tabulate them as follows:—

DICOTYLEDONS.	MONOCOTYLEDONS.
Embryo with two cotyledons.	Embryo with one cotyledon.
Primary root-growth exorhizal.	Primary root-growth often endorhizal.
Growth of wood with open bundles.	Growth of wood with closed bundles.
Leaves net-veined.	Leaves parallel-veined.
Parts of the flower arranged (as a rule) in fours or fives.	Parts of the flower arranged in threes.

Each of these classes is divided into sub-classes, of which

there are four in the Dicotyledons, and two in the Monocotyledons.

If we examine four such flowers as the Buttercup, Rose, Dead-nettle, and Hazel, we shall easily be able to understand the grouping.

In the first three specimens the flowers are **complete**; in the Hazel **incomplete**, the calyx and the corolla being absent. The Hazel stands, then, as a representative of the sub-class **Incompletæ**.

In the first two specimens the flowers are **polypetalous**; in the Dead Nettle the corolla is **gamopetalous**. The latter, therefore, is an example of the sub-class **Corollifloræ** or **Gamopetalæ**.

In the Buttercup the petals and stamens are **hypogynous**, which characterises the sub-class **Thalamifloræ**; whilst in the Rose they are **perigynous** (in some members of the group they are **epigynous**), and the sub-class is known as the **Calycifloræ**.

We may tabulate these results thus:—

Dicotyledons	Complete	Polypetalous	Petals and stamens hypogynous .	THALAMIFLORÆ
			Petals and stamens perigynous or epigynous . .	CALYCIFLORÆ
		Gamopetalous	. . . .	COROLLIFLORÆ
	Incomplete	. . . .		INCOMPLETÆ

The Monocotyledons are divided into two sub-classes: the **Petaloidæ**, which, like the Lily or Tulip, possess an evident perianth; and the **Glumaceæ**, which, like the Grasses, have their flowers arranged in those peculiar bracts known as glumes.

Each of these sub-classes is divided into several natural orders; in this work we shall deal with a few of the principal.

DICOTYLEDONS.

THALAMIFLORÆ.

Pistil apocarpous	Petals few, stamens many .	RANUNCULACEÆ.
Pistil syncarpous	Corolla cruciform, stamens tetradynamous . .	CRUCIFERÆ.
	Leaves opposite, stem swollen at nodes, sepals and petals 5. Free central placenta . .	CARYOPHYLLACEÆ.

CALYCIFLORÆ.

Pistil apocarpous	Flowers papilionaceous, stamens 10, mono- or di-adelphous, pistil monocarpellary	LEGUMINOSÆ.
	Flowers regular, petals 5, stamens and carpels numerous	ROSACEÆ.

Pistil syncarpous	Flowers arranged in umbels, petals and stamens epigynous, fruit a cremocarp	UMBELLIFERÆ.

COROLLIFLORÆ.

Flowers compound (in a capitulum)	Stamens syngenesious	COMPOSITÆ.
Flowers simple	Stem square, leaves opposite, corolla bilabiate, stamens didynamous, ovary 4-lobed	LABIATÆ.
	Stamens didynamous, ovary 2-lobed	SCROPHULARIACEÆ.
	Stamens five, ovary 4-lobed, inflorescence scorpioid .	BORAGINACEÆ.
	Stamens five. Free central placentation . . .	PRIMULACEÆ.

INCOMPLETÆ.

Flowers not in catkins	Calyx present, stamens opposite sepals, ovary 1-celled .	CHENOPODIACEÆ.
Flowers in catkins	Trees or shrubs . . .	AMENTACEÆ.

MONOCOTYLEDONS.

PETALOIDÆ.

Flowers irregular, ovary inferior, stamens gynandrous	ORCHIDACEÆ.
Flowers regular, ovary superior, 3-celled; perianth 6 divisions, stamens 6	LILIACEÆ.
Flowers regular, ovary inferior, 3-celled; perianth 6 divisions, stamens 6	AMARYLLIDACEÆ.

GLUMACEÆ.

Stems solid, sheaths of leaves not split, no ligule present	CYPERACEÆ.
Stem hollow, leaf-sheath split, ligule present . .	GRAMINACEÆ.

Each of these orders contains numerous plants, which are arranged in **genera** and **species**. A **genus** is an assemblage of plants which resemble one another more closely in general structure and appearance than they do othe species of plants. Thus, if we examine a Sweet Violet, a Dog Violet, and a Pansy, we find that although they differ in many minor points of detail, yet there is a great resemblance between them which causes them all three to be grouped under the genus *Viola*. By a **species** we mean an assemblage of individuals which whilst possessing the characteristics of the genus, possess in addition distinctive characters which separate them from the allied plants of the same genus. Thus the points in which the Sweet Violet, Dog Violet, and Pansy agree would be their

generic characters; whilst the points in which they differ are their specific characters. When the seed of a plant is grown it always reproduces the same species as the parent. In giving the name of a plant we place the generic name first, followed by the specific name. Thus the Sweet Violet is *Viola odorata*, the Dog Violet *Viola canina*, and the Pansy *Viola tricolor*.

Sometimes the pollen of one species will fertilise the ovule of a closely allied species, and a plant is thus obtained which combines the properties of both. Such a plant is said to be a **hybrid.**

We will now give a detailed account of the various orders, in each case mentioning a typical plant that should be carefully examined and compared with the description of the order.

DICOTYLEDONS.

THALAMIFLORAL ORDERS.

RANUNCULACEÆ.

Plant for examination, Buttercup (there are several species, any of them will answer for the purpose).

Note that the plant is an **herb** (the Clematis is a **shrubby**

Fig. 294.—Marsh Marigold (*Caltha palustris*). I. Part of plant. II. Fruit, consisting of follicles.

climber; otherwise the plants of the order are all herbs). If you have a specimen with leaves on the stem, they are arranged in an **alternate** manner (in the Clematis they are **opposite**). Often the bases of the leaves sheath around the stem. Examine the flower, making a vertical section through one (Fig. 165), and removing the parts of another. The **sepals** are **five** (in the order they vary from three to six, usually five), inferior. **Corolla** usually of **five petals** (varies in order from three to

fifteen), **hypogynous.** (In some plants of the order, as Marsh Marigold (Fig. 287) and Anemone, the corolla is absent.) **Stamens numerous, hypogynous; carpels distinct, numerous, superior** (sometimes in the order they are few). Fruit, an **etærio of achenes.** Some Ranunculaceæ have follicles (Figs. 265 and 294, II.). The flowers in the case of the Buttercup are **regular**; in other cases, as in the Aconite (Fig. 172) and Larkspur (Fig. 202), they are **irregular.** Plants of this order contain a watery acrid juice which is often poisonous. They grow in damp and marshy places, especially in the temperate regions.

Principal Plants of the Order.

Aconitum. The British plant, *A. Napellus*, the Monkshood, is easily recognised by its hooded calyx (Fig. 172), the petals being small and developed as nectaries (Fig. 203). The plant is very poisonous: the root has been mistaken for Horse Radish with fatal results; it is, however, much more conical in shape. It is most useful for medicinal purposes.

Adonis, Pheasant's Eye (Fig. 295). Much like the Buttercup, but the petals are bright scarlet and have no nectaries at the base. Flowers in the summer and early autumn in corn-fields.

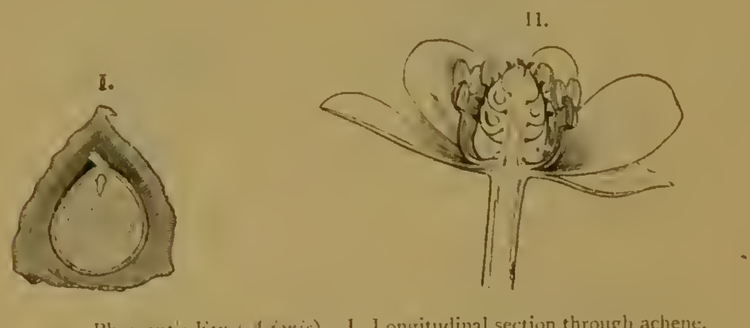

FIG. 295.—Pheasant's Eye (*Adonis*). I. Longitudinal section through achene. II. Longitudinal section through flower.

Anemone, Wind Flower. No corolla present, the calyx either coloured as in the Pasque Flower, or white as in the Wood-Anemone. Flowers in the spring; several species cultivated in our gardens for their showy colours.

Aquilegia, Columbine, with its five sepals petaloid, and five petals with spurs twisted up in a horn-like manner. Grown in gardens.

Caltha, Marsh Marigold (Fig. 294). A marsh plant with large flowers, yellow sepals, and no petals.

(Note, although this and other plants of the order are incomplete, the corolla being absent, yet we place them in this thalamifloral order because their general affinities resemble those of the other plants of the group. The same remark is true of many incomplete plants of other orders.)

Clematis, Old Man's Beard, or Traveller's Joy. A shrubby climber, with opposite leaves. The sepals are petaloid (greenish white in the British species), and petals absent. Many exotic Clematis are cultivated for their beautiful flowers.

Delphinium, Larkspur (Fig. 202). Flowers with one sepal spurred. Two petals small and united within the spurred sepal. Stavesacre is obtained from an exotic Delphinium.

Helleborus, Hellebore. Sepals large and petaloid, petals small and tubular. The Christmas Rose is an exotic Helleborus.

Myosurus, Mousetail. Small clawed petals, and carpels arranged in a dense cylindrical spike, whence the name.

Pæonia, Peony. Large showy flowers with deep red petals, and stamens inserted in a prominent disc.

Ranunculus, Crowfoot or Buttercup. A numerous genus, the flowers usually yellow, in some few cases white, but all characterised by the presence of nectaries at the base of the petals.

CRUCIFERÆ.

Typical plant, Wallflower (*Cheiranthus Cheiri*) (Fig. 296). Note, the **stem** is **shrubby** below and **herbaceous** above (the plants of the order are generally herbs, sometimes under-shrubs). **Leaves alternate** and **exstipulate**; flowers are arranged in a raceme; **calyx four sepals**, saccate; **corolla four petals, cruciform**; **stamens** six in number, **tetradynamous** (Fig. 213) (note, in cultivation there is always a tendency for the stamens to become the same length); pistil with single ovary and two stigmas; fruit a **siliqua**. (Besides the siliqua there is also met with in the order the **silicula**, the **lomentum**, and an indehiscent fruit as seen in the Woad, Figs. 271 and 297.) This is a large and widely distributed order, easily recognised by the cruciform corolla and tetradynamous stamens. **No plant of this order is poisonous.** Many are used for food purposes. Many of the plants contain sulphur, and are pungent in taste.

Principal Plants of the Order.

Brassica. A large and important genus. Leaves irregularly pinnate; flowers yellow; fruit a siliqua, often beaked at the end.

Principal species are—*B. Sinapis*, Mustard; *B. oleracea*, which yields all the varieties of Cabbage, Cauliflower, Broccoli, Brussels Sprouts, and Savoys; *B. Napus*, Rape; *B. campestris*, Swedish Turnip, the seeds of which with some other species yield colza oil; *B. Rapa*, Turnip.

Capsella (Fig. 102), Shepherd's Purse. One of the com-

Fig. 296. — Wallflower (*Cheiranthus Cheiri*), Siliquosæ. Part of plant.

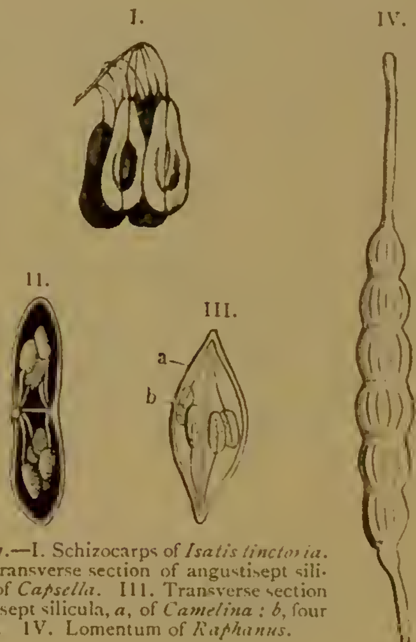

Fig. 297.—I. Schizocarps of *Isatis tinctoria*. II. Transverse section of angustisept silicula of *Capsella*. III. Transverse section of latisept silicula, *a*, of *Camelina*: *b*, four seeds. IV. Lomentum of *Raphanus*.

monest weeds, and a good example of a silicula-bearing crucifer. Flowers small, white; fruit a silicula with replum running across the narrow diameter (*angustisept*) (Fig. 297, II.).

Cheiranthus, Wallflower.

Cochlearia. Fruit a silicula with replum running across the broad diameter (*latisept*) (Fig. 297, III.), so that the fruit is nearly globose. There are two British species, the Horse radish and the Scurvy Grass.

Crambe, Sea Kale. Fruit two-jointed, upper joint with one seed indehiscent, lower joint forming a stalk above the calyx; might be mistaken for a gynophore.

Iberis, Candytuft. Petals unequal, the two exterior petals larger than the interior ones; fruit silicula, angustiseptate.

Isatis, Dyer's-woad. Small numerous yellow flowers; fruits pendulous, flattened, indehiscent. The plant yields a blue dye.

Lepidium, Cress. Numerous small white flowers, petals equal; fruit silicula, angustiseptal, one seed in each cell.

Matthiola, Stock. Plants hoary from minute hairs; large purple flowers; fruit a cylindrical siliqua.

Nasturtium, Watercress. Small yellow or white flowers; fruit a siliqua, generally somewhat curved. (This must not be confounded with the garden Nasturtium, which is a Tropæolum, belonging to quite a different order.)

Raphanus, Radish. Fruit a lomentum.

CARYOPHYLLACEÆ.

Typical plant, the Greater Stitchwort (*Stellaria Holostea*).

Note, the plant is **herbaceous**; the **leaves** are **opposite, exstipulate**; in some few genera there are small scarious (scaly) stipules. The **stem** is **swollen** at the **nodes**. **Inflorescence** a **dichotomous cyme** (Fig. 156), usually to be found in the order; calyx five separate sepals (in some genera calyx is gamosepalous); corolla five petals notched (this is often met with in the order, and in many cases the petals are unguiculate, Figs. 180, 181, and 195); stamens ten, seldom in the order fewer; pistil with **syncarpous** ovary, three styles (in the order the number varies from two to five); **free central placentation**, very characteristic of order. A very wide-spread order, found in all parts of the temperate regions, especially in the Northern Hemisphere.

Principal Plants of the Order.

Cerastium, Mouse-ear Chickweed (Fig. 156). A numerous genus. Flowers with separate sepals, two-cleft petals, five styles; the fruit often prolonged in a horn-like manner, and opens by ten valves or teeth.

Dianthus. Pink (Fig. 147). Calyx gamosepalous, with two or more scales (bracts) outside, two styles. There are several species cultivated, such as the Clove Pink or Carnation, Maiden Pink, Cheddar Pink, Sweet William, etc.

Lychnis (Fig. 194). Gamosepalous calyx, ebracteate; ovary with five styles. Several species grow as common weeds, such as Ragged Robin, Evening Campion, and Corn Cockle.

Silene. Differs from the Lychnis in having three or four styles. Several species of Campion and Catchfly.

Stellaria. Differs from the Cerastium in having three styles, and capsules opening by six valves or teeth. Several species of Chickweed and Stitchwort.

We now come to the—

CALYCIFLORAL ORDERS.

LEGUMINOSÆ.

Typical plant, Sweet Pea (*Lathyrus odoratus*, Fig. 93).

Note, the plant is herbaceous (in the order there are also shrubs and trees); leaves **alternate, stipulate**, often compound and pinnate, as in this case: calyx **gamosepalous**, with five teeth; corolla **papilionaceous**; **stamens** ten, **diadelphous** (in several genera they are **monadelphous**); pistil **monocarpellary**; fruit a **legume**.

FIG. 298.—Sensitive Plant (*Mimosa pudica*).

There are three sub-orders of this important order. All the British plants, however, belong to one of these, the *Papilionaceæ*, which is distinguished by having papilionaceous flowers and hence can be easily recognised.

In the other two sub-orders, which are exclusively extra-European, the flowers are regular, the petals being imbricated in the *Cæsalpineæ*, and valvate in the *Mimoseæ* (Fig. 298). The order is a very large one and widely distributed, very varied in its properties, some of the plants being most useful as food and fodder plants, others as drugs, whilst others again are poisonous.

Principal British Plants.

Astragalus, Milk Vetch. Leaves imparipinnate: stamens diadelphous: keel of corolla blunt; legume not jointed, but more or less divided into two cells by a partition. A good fodder plant.

Genista, Greenweed and Dyer's Weed. Leaves simple; stamens monadelphous; calyx bilabiate. The Dyer's Weed (*G. tinctoria*) yields a yellow dye.

Lathyrus, Peas and Vetchlings. Leaves inparipinnate, ending in tendrils, with few leaflets, and sagittate or half-sagittate stipules; stamens diadelphous, style flattened above. Several

species used as fodder plants. The Sweet Pea (*L. odoratus*) and Everlasting Pea (*L. latifolius*) are exotic species. The edible Pea is separated into another genus, *Pisum.*

Lotus, Bird's Foot Trefoil. Leaves trifoliate, with large leaf-like stipules; stamens diadelphous; calyx with five equal teeth; legume imperfectly many celled. A good fodder plant.

Medicago, Medick or Lucerne. Leaves trifoliate; stamens diadelphous; legume more or less spirally twisted (Fig. 299),

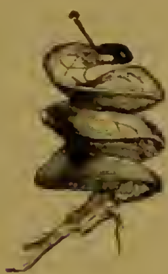

FIG. 299.—Twisted legume of Lucerne (*Medicago sativa*).

FIG. 300.—Abbreviated inflorescence of Clover.

sickle-shaped, indehiscent. Much cultivated as a fodder plant, especially *M. sativa*, the Lucerne.

Melilotus, Melilot. Leaves trifoliate; flowers in long loose racemes: stamens diadelphous; legumes with one or very few seeds, longer than the calyx. Fodder plants.

Onobrychis, Sainfoin. Leaves imparipinnate; stamens diadelphous; legume flat, hard, one-seeded, and indehiscent. A valuable fodder plant.

Sarothamnus, Broom. Leaves trifoliate, three digitate leaflets; stamens monadelphous; calyx campanulate, with two lips, minutely toothed; legume flat, many-seeded.

Trifolium, Trefoil or Clover. Leaves trifoliate; flowers in abbreviated heads (Fig. 300); stamens diadelphous; legume few seeds, concealed within calyx and often indehiscent. Many species are very largely cultivated as fodder plants.

Ulex, Furze. Leaves simple and acerose; two sepals; stamens monadelphous.

Vicia, Vetch and Tares. Leaves imparipinnate, ending in tendrils and with many leaflets; stamens diadelphous; style

threadlike. Very useful fodder plants. One exotic species, *V. Faba*, gives us the Broad Bean.

The following are important exotic plants belonging to this sub-order: Used for food purposes: *Arachis*, Ground Nuts; *Ervum*, Lentils; *Phaseolus vulgaris*, the French Bean; and *P. coccineus*, the Scarlet Runner; *Pisum*, Pea. Used for various purposes: Balsam of Tolu, Indigo, Kino, Laburnum, Liquorice, Ordeal Bean, Rosewood, Tonquin Bean.

The following important plants belong to the other two sub-orders: Braziletto Wood, Cassia, Copal, Copaiba Balsam, Locust Tree, Logwood, Sandal Wood, Sanders Wood, Sensitive Plant, Tamarind.

ROSACEÆ.

Typical plant, Bramble (*Rubus fruiticosus*); also compare with it, Blackthorn or Sloe, Rose, and Apple.

Note, the plant is a shrub (in the order there are also herbs and trees): leaves **alternate**, stipules present, adhering to the petiole (stipules are seldom absent in the order); calyx gamosepalous, five divisions, inferior (there may be but four divisions to the calyx—in the Rose it forms a cup-like tube enclosing the carpels (Fig. 196), and in the Apple and Pear it is adherent to the carpels, Figs. 301 and 279); corolla **polypetalous, five petals, perigynous** (in a few cases there are four petals, and in some cases none); **stamens numerous, perigynous**; **carpels numerous** (in the Blackthorn there is but one), **apocarpous**; fruit an **etærio of drupes.** (In the order the fruit is very various. Thus it may be a single **drupe**, Blackthorn: **etærio of achenes**, Strawberry; **cynarrhodum**, Rosê; **follicles**, Meadow Sweet; or **pome**, Apple.)

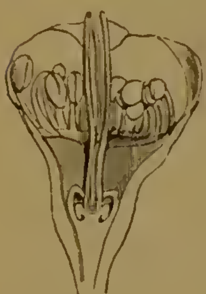

FIG. 301.—Longitudinal section through the flower of the Pear.

This large and important order is widely distributed, especially in the temperate regions. Many of the plants very much resemble those of the Ranunculaceæ, but a careful examination will show the great distinction from that order in the perigynous stamens and petals.

The Rosaceæ are divided into four sub-orders:—

1. DRUPACEÆ or AMYGDALEÆ. Trees or shrubs with simple leaves; fruit a drupe. Many parts of the plants contain hydrocyanic or prussic acid.

Prunus is the only British genus of this sub-order. It has

the nut of the drupe smooth or slightly seamed. The native species include the Sloe, Wild Plum, and Cherry. Amongst exotic species of the same genus which are largely cultivated are the Apricot, Cherry Laurel, and Portuguese Laurel.

Amygdalus is the exotic genus which yields us Almonds, both bitter and sweet, Peaches, and Nectarines.

2. ROSEÆ. Shrubs or herbs; stipules adherent; ovaries one or more, not adherent to calyx; fruit etærio or follicles.

Principal British Plants.

Agrimonia, Agrimony. Flowers in loose spikes; calyx five-cleft, top-shaped, with hooked bristles; stamens not more than fifteen; carpels two. The plant was formerly used by herbalists.

Fragaria, Strawberry. Calyx ten-cleft, in two rows; fruit an etærio of achenes on an enlarged and fleshy receptacle.

Potentilla differs from the Strawberry principally in the fruit being on a dry receptacle; *P. Tormentilla* has but four petals.

Rosa. Calyx urn-shaped; fruit a cynarrhodum. There are several species of wild Roses and Briars, from which many of our cultivated Roses are obtained; others come from exotic species.

Rubus, Bramble. Calyx five-cleft; fruit etærio of drupes.

I. II.

FIG. 302.—*Sanguisorba officinalis*. I. Flower. II. Fruit.

The genus includes the Raspberry, Blackberry, Dewberry, and Cloudberry.

Spiræa. Calyx five-cleft; fruit three to twelve follicles. Several species of Meadow Sweet. Some of the exotic plants are cultivated for their flowers.

3. SANGUISORBEÆ. Herbs or under-shrubs; flowers often unisexual; petals absent (Fig. 302); carpel solitary; fruit an achene (Fig. 302, II.).

British Plants.

Alchemilla. Calyx eight-cleft, in two rows; stamens one to four. The species of Lady's Mantle and Parsley Piert are used as fodder plants.

Poterium, Salad Burnet. Calyx four-cleft, petaloid; flowers unisexual; stamens numerous. A good salad plant.

Sanguisorba, Great Burnet. Calyx four-cleft, petaloid; stamens four. Grown in Germany as a fodder plant.

4. POMEÆ. Trees or shrubs; carpels one to five, adhering more or less to one another, and sunk in the receptacle, thus becoming inferior; fruit a pome.

British Plants.

Cratægus, May or Hawthorn. Fruit hard or bony; calyx divisions sharp.

Mespilus, Medlar. Differs from the May in its larger flowers and foliaceous calyx divisions.

Pyrus. Calyx divisions small; fruit fleshy. Its species include the Apple, Pear, Rowan tree or Mountain Ash, and Wild Service tree. The exotic genus *Cydonia* yields us the Quince.

From many of the plants of this sub-order also prussic acid is obtainable.

UMBELLIFERÆ.

Typical plant, Cow Parsnip (*Heracleum Sphondylium*).

Note, the stem is **herbaceous, hollow,** except at the nodes, leaves **alternate, sheathing at base, bi- or tri-pinnate** (leaves in the order are generally much divided); flowers in **compound umbels** (in *Hydrocotyle* the umbels are simple, in *Sanicula* and *Eryngium* the flowers are arranged in tufted heads); **calyx adherent** to ovary, free limb absent, or as five small teeth; corolla **polyyetalous, five petals, epigynous**; **stamens five, epigynous**; pistil **inferior, two cells, two styles**; fruit a **cremocarp.**

This is a very large and wide-spread order, easily recognisable by its umbellate flowers and two-celled ovary with cremocarp. The plants of the order are, however, very difficult to identify, as the distinctions of the genera and species depend principally upon small points of detail in the structure of the seed and the fruit.

The properties of the order are very various; some

members yield us food plants, others are very poisonous; and again others yield useful drugs.

Principal British Plants.

Angelica. Fruit two flattened carpels united by their faces, with three sharp ridges at the back of each, and two at the side expanding out. The leaf-stalks are used candied as sweet-meats.

Æthusa, Fool's Parsley (Fig. 303). Fruit nearly globose; no general bracts, but three partial bracts to each secondary

FIG. 303.—I.—*Æthusa Cynapium* (Fool's Parsley). II. Fruit. III. Section of fruit.

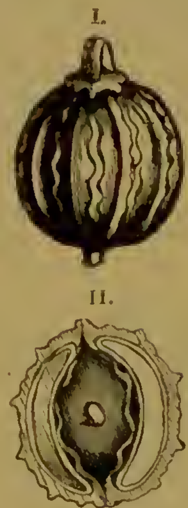

FIG. 304.—I. Fruit of Coriander (*Coriandrum sativum*). II. Transverse section.

umbel, which hang down (Figs. 303 and 151). A very poisonous plant, liable to be mistaken for true Parsley; distinguished by its bracts.

Apium, Celery. Fruit roundish egg-shaped, the carpels flattened and united by the narrow edge, five slender ridges on each; no bracts. In the wild state poisonous; when blanched by etiolation, fit for eating.

Bunium, Earth Nut. Oblong fruit of flattened carpels united by narrow edge with five blunt ridges; no general involucre, but a slight partial one. The tuberous root is esculent.

Carum, Caraway. Oblong fruit of flattened carpels united by narrow edge with five slight ridges; no bracts, or at most

but one general bract. Roots and leaves are edible, and fruit used under the name of Caraway seed.

Chærophyllum, Chervil. Fruit contracted at sides, with short beak, five blunt ridges on each carpel; several partial bracts. Formerly cultivated as a culinary herb.

Cicuta, Water Hemlock. Fruit of two globose carpels united by narrow edge with five broad flattened ridges. A most virulent poison.

Conium, Hemlock. Fruit egg-shaped, with five wavy ridges on each lobe. Plant emits, when bruised, a nauseous "mousy" smell. A most poisonous plant, useful medicinally.

Coriandrum, Coriander. Fruit globose (Fig. 304), scarcely prominent ribs, very aromatic. Fruit used under name of Coriander-seed.

Crithmum, Samphire. Leaves succulent; fruit elliptical, with spongy lobes. The plant is edible, being used as a pickle.

Daucus, Carrot. Fruit slightly flattened, prickly (Fig. 305), there being rows of prickles between the bristly ridges. The root is edible, forming the cultivated Carrot.

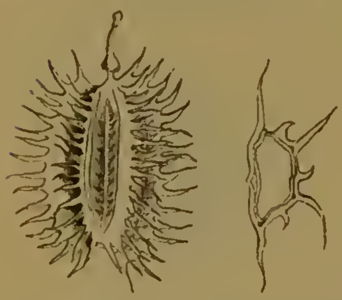

FIG. 305.—I. Fruit of Carrot (*Daucus Carota*). II. Transverse section: the four secondary ridges are conspicuous; of the primary ridges the two lateral ones are scarcely visible, the median (carina) and intermediate ones are spiny.

Eryngium, Sea Holly. Flowers in dense prickly heads.

Fœniculum, Fennel. Fruit elliptical (Fig. 268), carpels with five bluntly keeled ridges. Leaves much divided. Plant esculent.

Helosciadium, Marshwort, or Fool's Watercress. Plant much resembling Watercress, but leaves more pointed and serrate. No general bracts, five partial. Very poisonous, hence importance of distinguishing it from Watercress.

Heracleum, Cow Parsnip. Very common weed. Flowers white, the outer petals of umbel larger than the inner ones, else very like the true Parsnip. Might be used as an esculent herb.

Hydrocotyle, White Rot. A marsh plant with simple umbels and peltate leaves.

Ligusticum, Lovage. Fruit elliptical, not flattened, the five ridges to each lobe sharp and winged. Used as a vegetable in many parts.

Myrrhis, Sweet Cicely. Very aromatic; fruit large, with

deep furrows between carpels, and five sharply keeled ridges. Potherb.

Œnanthe, Water Dropwort. Fruit egg-shaped, with five blunt ridges; petals notched. Very poisonous plant.

Pastinaca, Parsnip. Fruit very flat, with broad border; flowers yellow, all small. Root edible.

Petroselinum, Parsley. Fruit very much like Celery; numerous partial bracts. Esculent plant.

Pimpinella, Burnet Saxifrage. Fruit much like Celery, but ribs less prominent. Aniseed is obtained from an exotic species of this genus.

Sanicula, Sanicle. Flowers in tufted heads, imperfect, the outer pistillate, inner staminate. Was formerly supposed to possess healing qualities.

The following exotic plants belong to this important order:—*Anethum*, Dill; *Anthriscus*, Chervil; *Cuminum*, Cummin; *Dorema*, which yields gum ammoniacum; *Ferula*, yields asafœtida; and *Opoponax*, yielding the gum resin of that name.

COROLLIFLORAL ORDERS.

COMPOSITÆ.

Typical plant Sunflower (*Helianthus annuus*); also compare with it a Dandelion and a Daisy.

Note, the plant is **herbaceous** (some exotic Compositæ are shrubby); leaves exstipulate; flowers arranged in a **capitulum** surrounded by an **involucre** of bracts. The flowers are of two kinds—those of the ray, which are **ligulate,** and those of the disc, which are **tubular** (note, in the Dandelion all the flowers are ligulate). Examine one of the **ray** flowers; at the base the **inferior ovary,** and above it the yellow **ligulate** corolla: on slitting this there is to be seen a reduced style on the ovary, and the stamens are abortive, the flower being **neuter.** Examine one of the **disc** flowers; note, the **inferior** ovary with two scales above, forming all that is left of the calyx (in the Dandelion the calyx is a **pappus**); above this a **tubular** yellow corolla with five teeth. On slitting open the corolla we find **five stamens, epipetalous** and **syngenesious**; **single style** and **bifid stigma**; fruit an **achene.**

The plants of this order are easily recognised by their flowers being arranged in capitula with **syngenesious** stamens, the latter characteristic distinguishing them from the allied Teasel family.

It is the largest of all natural orders, containing one-tenth of the known plants of the world. The members of the group differ much in their properties and uses.

The British plants are divided into two sub-orders :—

TUBULIFLORÆ, which have all their florets (as the Corn Bluebottle), or inner ones only (as Daisy), tubular.

LIGULIFLORÆ have all their florets ligulate (as Dandelion).

Principal British Plants.

TUBULIFLORÆ.

Anthemis, Chamomile. Flowers arranged on a convex receptacle, with tubular perfect florets in disc, and ligulate pistillate flowers in ray ; the receptacle has scales between the flowers. Used medicinally.

Arctium, Burdock. All flowers tubular, perfect, and in a convex head ; a globose involucre present, with hooked points to the bracts ; pappus short. Various parts of this plant may be eaten, either as a salad or cooked (Fig. 146).

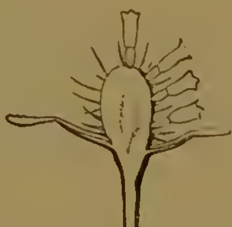

FIG. 306.—Common receptacle of *Anthemis arvensis*, with paleæ between the flowers.

FIG. 307.—Neuter flower of *Centaurea Cyanus*.

Artemisia, Wormwood. All flowers tubular, perfect, in a flat head ; no pappus ; only few flowers in the head. A very bitter plant, used in the manufacture of *absinthe*.

Bellis, Daisy. Flowers as in Anthemis, but without scales on receptacle ; involucre of two rows of equal bracts.

Carduus, Thistle. All florets tubular, perfect, in a convex head ; involucre swollen below, with thorn-like scales.

Centaurea, Knapweed and Bluebottle. Florets tubular, inner perfect, outer large and neuter, somewhat irregular (Figs. 182 and 307).

Chrysanthemum. Disc florets tubular and perfect, ray

florets ligulate and pistillate; involucre flat; receptacle naked, and no pappus.

Inula, Elecampane. Disc florets tubular and perfect, ray ligulate, all yellow; pappus present; many-rowed involucre. Formerly used as a sweetmeat.

Senecio, Ragwort and Groundsel. Disc florets tubular and perfect, ray ligulate and pistillate (latter wanting in Groundsel), all yellow; simple pappus; scales outside the involucre.

Tussilago, Coltsfoot. Flowers appear in spring before the leaves; flower-stalks covered with scale-like bracts; few disc florets, tubular, perfect; many narrow ray florets, ligulate, pistillate; all yellow. Often used as a remedy for colds and coughs.

LIGULIFLORÆ.

Cichorium, Chicory. Flowers blue, sessile, upon tough stems; involucre of two rows. It is the root which is used to mix with coffee.

Lactuca, Lettuce. Few florets, with hairy pappus and oblong imbricated involucre. The garden Lettuce is an exotic species of this genus.

Taraxacum, Dandelion. Lyrate leaves, radical; flower-stalk hollow, leafless; outermost bracts of the involucre recurved; receptacle dotted. The young plant forms a good salad, and is often used by herbalists as a tea.

The following exotic genera yield important plants:—*Arnica*, used medicinally in case of bruises; *Calendula*, Marigold, also used as an external remedy for cuts, and to adulterate saffron; *Carthamus*, Safflower, or Bastard Saffron, often used instead of true Saffron to yield the pink dye; *Cynara*, Artichoke; *Helianthus*, Jerusalem Artichoke and Sunflower.

LABIATÆ.

Typical plant, White Dead Nettle (*Lamium album*, Fig. 158).

Note, the plant is **herbaceous**; stem **square**; leaves **opposite**; flowers in **verticillasters**; calyx **inferior**, five-toothed (it may be ten-toothed in the order); corolla (Figs. 308 and 191) **bilabiate, ringent** (in some cases the corolla is almost regular, Fig. 309); stamens **didynamous, epipetalous**, Fig. 214 (in the Sage there are only two stamens with branched connective, Fig. 217; and in the Mint the four stamens are equal, Fig. 302); pistil **superior, four-lobed**; fruit a **carcerulus** (Fig. 272).

The four-lobed ovary is a most important point, as it

distinguishes the order from the next, where there are only two lobes. **No plant of the order is poisonous.** Many contain aromatic essential oils, and are used for flavours and perfumes. It is chiefly distributed in temperate regions.

Principal British Plants.

Calamintha, Wild Basil and Basil Thyme. Calyx with thirteen nerves upon it; corolla longer than calyx, lower lip with three broad lobes; outer stamens longest, but not diverging from inner ones.

Lamium, Dead Nettle. Calyx ten ribs and five teeth; corolla with upper lip arched, lower lip with large middle lobe, two side ones small.

Marrubium, White Horehound. Stamens shorter than the

FIG. 308.—*Lamium album.* Longitudinal section of flower.

FIG. 309.—Nearly regular flower of Peppermint (*Mentha piperita*).

tube of the corolla; calyx with five or ten teeth and ribs; upper lip of corolla deeply notched. Used as a remedy for coughs.

Mentha, Mint. Corolla nearly regular; stamens, four, equal. There are many species used as flavours and odours; principal are Spear Mint, Peppermint, and Pennyroyal.

Origanum, Marjoram. Flower in panicles or corymbs; a bract under each flower. Used as a potherb.

Salvia, Sage or Clary. Two stamens with branched connectives.

Teucrium, Germander. Upper lip of corolla apparently wanting, but appearing as two small teeth, one on each side of the lower lip.

Thymus, Thyme. Calyx bilabiate, upper lip three-toothed, lower two-toothed; corolla with upper lip flat and erect, lower spreading; outer stamens diverging from the inner ones.

Amongst exotic genera we have *Hyssopus*, Hyssop; *Lavandula*, Lavender; *Melissa*, Balm; *Ocymum*, Basil; *Pogostemon*, Patchouly; *Rosmarinus*, Rosemary; *Satureia*, Savory.

SCROPHULARIACEÆ.

Typical plant, Great Snapdragon (*Antirrhinum majus*, Fig. 145).

Note, the plant is **herbaceous**; leaves **opposite** (rarely alternate); corolla **bilabiate, personate,** Fig. 192 (it may be almost regular, as in the Foxglove, Fig. 310; or ringent, as in the *Scrophularia*); stamens **epipetalous, didynamous** (only two in *Veronica*, and five in Mullein); pistil **superior, two-lobed; dumb-bell-shaped placenta** (Fig. 311).

It is most important to note the two-lobed ovary, which distinguishes this order from the last, as many plants of the Scrophulariaceæ are poisonous. Distributed all over the world.

FIG. 310.—Flower of Foxglove (*Digitalis purpurea*).

FIG. 311.—Bilocular ovary of *Antirrhinum*, with axile placentæ.

Principal British Plants.

Antirrhinum, Snapdragon. Corolla personate, not spurred, but with a protuberance at base.

Digitalis, Foxglove. Corolla irregularly bell-shaped; leaves alternate. Very poisonous; used medicinally.

Euphrasia, Eyebright. Calyx four-cleft; corolla ringent, upper lip two-lobed, spreading.

Linaria, Toadflax. Differs from Snapdragon in having spurred corolla.

Melampyrum, Cow Wheat. Calyx four-cleft; corolla ringent, upper lip compressed laterally.

Rhinanthus, Rattle. Differs from the last in having the calyx much swollen, with four small teeth.

Scrophularia, Figwort. Calyx five-lobed; corolla ringent, nearly globose; flowers small. Poisonous.

Verbascum, Mullein. Corolla rotate, five-lobed; five stamens.

Veronica, Speedwell. Corolla rotate, four lobed; two stamens.

Euphrasia, Melampyrum, and Rhinanthus are semi-parasites (see p. 89).

BORAGINACEÆ.

Typical plant, Forget-me-not (*Myosotis palustris*, Fig. 157).

Note, plant **herbaceous** (in many Boraginaceæ the herbage is very coarse and rough with numerous hairs—**hispid**); leaves **alternate**; flowers in a **scorpioid cyme**; calyx **inferior, gamosepalous, five-lobed**; corolla **regular, gamopetalous, five-lobed**, the throat closed by five short notched scales (in some Boraginaceæ the corolla is almost irregular, and in some cases the scales are absent); stamens **five, epipetalous**; pistil **superior, four-lobed**, composed of two carpels, each divided by its dorsal suture being bent inwards; style **gynobasic**—that is, growing up between the four ovaries and looking as though it were a prolongation of the thalamus.

The plants of the order are chiefly natives of the temperate regions of the Northern Hemisphere.

Principal British Genera.

Anchusa, Alkanet. Corolla funnel-shaped with a straight tube, the throat closed by five blunt white scales. An exotic species, cultivated in S. Europe, has a dark blood-red root, which is chiefly employed to colour oils for perfumery and other purposes.

Borago, Borage. A very coarse hispid herb; corolla rotate, with five broad notched scales (Figs. 188 and 198). It contains nitrate of potash, which gives coolness to beverages in which it is steeped, hence is used in claret cup.

Echium, Viper's Bugloss. A very coarse hispid herb; corolla unequally five-lobed, the throat naked; stamens much protracted.

Myosotis, Forget-me-not and Scorpion Grass. Corolla small and rotate, the throat closed by five short notched scales.

Symphytum, Comfrey. Coarse herb; stem more or less winged by the decurrent leaves (Fig. 142); corolla campanulate, with five awl-shaped scales. The young leaves and shoots are sometimes eaten as a vegetable.

PRIMULACEÆ.

Typical plant, Common Primrose (*Primula vulgaris*).

Note, an herb with **radical leaves** (many plants of the order, however, possess cauline leaves); flowers **regular**; calyx **gamosepalous, inferior, five-cleft**; corolla **gamopetalous, five-cleft**; stamens **five, epipetalous,** OPPOSITE THE COROLLA LOBES (the flowers being dimorphic, the stamens are sometimes inserted just in the throat of the corolla, sometimes some little distance down the tube); ovary **one-celled**; **free central placentation, single style**; stigma **capitate.**

The plants grow mostly in the north temperate zone, especially in mountainous districts.

Principal British Genera.

Anagallis, Pimpernel (Fig. 138). Calyx split to the base; corolla rotate; hairy stamens; capsule dehiscing transversely (Fig. 258).

Cyclamen, Sow Bread. Calyx split halfway down; corolla rotate, with reflexed segments; capsule dehiscing by five teeth.

Hottonia, Water Violet. A water plant with submerged divided leaves; calyx divided almost to the base; corolla salver-shaped; capsule dehiscing by five teeth.

Lysimachia, Loosestrife, Yellow Pimpernel, Moneywort, Creeping Jenny, etc. Calyx divided to the base; corolla rotate; stamens without hairs; capsule dehiscing by valves.

Primula, Primrose, Cowslip, Oxlip. Calyx tubular, five-cleft; corolla salver-shaped or funnel-shaped.

INCOMPLETÆ.

CHENOPODIACEÆ.

Typical plant, White Goosefoot (*Chenopodium album*).

Note, plant **herbaceous** (some plants are somewhat shrubby), **succulent**; leaves **alternate** (often in the order very succulent); flowers inconspicuous (in many plants of the order we have

separate staminate and pistillate flowers); calyx **inferior, five-lobed** (in the order it is from two- to five-lobed, usually five), persistent (often in the order it very much enlarges as it surrounds the fruit); corolla **absent**; stamens **five, opposite the sepals** (rarely in order one or two); pistil **superior, syncarpous**; two or three styles.

This order is widely distributed, the plants growing especially in salt marshes. Many of the plants are esculent, others were formerly much employed in the manufacture of soda, which was obtained from their ashes, known as *barilla*.

Principal British Genera

Atriplex, Orache and Purslane. Flowers generally unisexual; perianth five-cleft in staminate and two-cleft in pistillate flowers, very much enlarged round fruit, which is one-seeded. Several species of common weeds.

Beta, Beet. Fruit one-seeded, immersed in succulent base of calyx; three small bracts beneath the calyx. Edible; much cultivated for manufacturing sugar. Mangel-wurzel is a variety of the beet.

Chenopodium. Flowers differ from above in having no bracts, and the perianth not becoming fleshy on fruiting. There are several species. *C. album* is the commonest, a plant which overruns gardens and grows on waste places. It may be used as a potherb. *C. Bonus-Henricus*, Good King Harry, or All Good, is also edible. *Spinacea oleracea*, Spinach, is an exotic genus with four styles cultivated for food purposes.

AMENTACEÆ.

Typical plant, Common Hazel (*Corylus Avellana*, Fig. 162).

Note, the plant is a **shrub** or **small tree** (trees and shrubs are met with in the order); leaves **alternate**; flowers **in catkins, monœcious** (in many plants of the order, as the Willow, the flowers are **diœcious**): staminate catkins **pendulous**; numerous **wedge-shaped bracts**; no perianth; eight stamens attached to each bract, Fig. 312 (in the order the number of stamens present varies from two upwards, and a slight perianth is sometimes present); pistillate inflorescence a bud-like catkin with two flowers within surrounded by numerous bracts, each flower consisting of a two-celled ovary with two red stigmas (in the order the pistillate catkins are either pendulous like the staminate, with one, two, or three flowers on each scale-like

bract, or in a bud-like head with two or three flowers in the centre); fruit a one-seeded nut (in some plants of the order a capsule). This is an important and extensive family, distributed all over the globe, especially in temperate regions, and yields a large number of timber trees as well as esculent plants.

FIG. 312.—The Hazel (*Corylus Avellana*). I. Male flower. II. Female flower. III. Fruit with laciniated spurious cupule.

It is divided into several sub-orders, four of which are represented in this country, viz.:—

SALICINEÆ. Generally diœcious; pistillate flowers in catkins; fruit a capsule.

BETULINEÆ. Flowers generally monœcious; pistillate flowers in catkins; fruit a flat nut.

MYRICEÆ. Flowers generally diœcious; pistillate flowers in catkins; fruit a false drupe from the scaly bracts becoming fleshy.

CUPULIFERÆ. Pistillate flowers in tufts or spikes; bracts grow up around fruit to form a cup or cupule (Figs. 281 and 312).

Principal British Plants.

SALICINEÆ.

Populus, Poplar. Stamens eight to thirty; stigmas deeply forked, slight; perianth present. Several species grown as ornamental and timber trees.

Salix, Willow and Osier. Stamens one to five; stigmas slightly forked; no perianth present. Very numerous species.

BETULINEÆ

Alnus, Alder. Fruit not winged; two flowers on each pistillate bract. The wood is very durable and yields good charcoal.

Betula, Birch. Fruit winged, three in each bract (Fig. 270). The timber is utilised, and from the sap Birch wine, which is used medicinally, is obtained.

MYRICEÆ.

Myrica, Sweet Gale. Diœcious; four to eight stamens, two stigmas.

CUPULIFERÆ.

Carpinus, Hornbeam. Stamens twelve to each scale; pistillate catkins slender and loose; a three-lobed scale (perianth?) to each pistil, which enlarges with the fruit (Fig. 313). Used for timber.

Corylus, Hazel. Stamens eight to each scale; two pink stigmas to each ovary; fruit a nut in a leafy involucre. Filberts, Cobs, and Barcelona nuts are varieties of Hazel.

Fagus, Beech. Staminate flowers in a globose catkin; stamens five to fifteen; fruit two three-cornered nuts in a prickly involucre. The wood yields good charcoal.

Fig. 313.—Fruit of the Hornbeam (*Carpinus Betulus*), with its three-lobed perianth.

Quercus, Oak. Stamens five to ten; staminate flowers in a long drooping catkin; fruit surrounded with a cup-shaped involucre. The timber is most valuable for many purposes. Cork is the outer bark of *Q. suber*. Oak-galls and oak-apples are also obtained from various species, whilst the bark is often used for tanning.

Exotic plants of interest belonging to this order are—*Carya*, Hickory; *Castanea*, Sweet Chestnut; *Juglans*, Walnut; *Liquidambar*, species of which yield resins known as storax and liquidambar; and *Ostrya* Ironwood.

MONOCOTYLEDONS.

PETALOIDÆ.

ORCHIDACEÆ.

Typical plant, Spotted Orchis (*Orchis maculata*).

Note, the plant is **herbaceous**; flowers **very irregular** (Fig. 314); perianth **superior** (note, the twisted ovary may be mistaken for a stalk), **six-lobed**; there are three outer and three inner segments, all petaloid; one of the inner lobes is flattened out, forming a **lip** or **labellum**, and is also prolonged below into a **spur**. Behind the labellum there is a short column terminating in a knob, the **rostellum** (Fig. 314, II., R), and a single stamen with two anther lobes (Fig. 314, II, L, P), containing not free pollen, but a mass united together and stalked, a **pollinium** (Fig. 314, IV.). Below the rostellum and stamen is the stigma (Fig. 314, II., ST), so that the arrangement is **gynandrous**. Below is the one-celled ovary with three parietal placentas.

Taking a flower which has but recently expanded, push gently a sharpened pencil into the spur. It is found that on touching the rostellum its pouch-like membrane is pushed down, and the pencil comes in contact with the viscid substance at the base of the pollinia. On removing the pencil one or both of the pollinia are removed attached to it. It will be found after removal they gradually bend over towards the point of the pencil.

If an insect, such as a bee, visits the plant for the honey contained in the spur, it presses its head against the rostellum, and flies away with the two pollinia attached; on visiting a second flower these have bent forward, so that instead of returning to the same place from which they were taken in the previous flower, they strike against the viscid stigma, and some of the pollen remains attached.

The exact method of fertilisation varies in the different plants of this order. It is very widely distributed, especially in tropical regions. Many of the plants are **epiphytes**, or air plants: clinging to the trunks of trees, their roots are green with stomata, and never reach the soil; they absorb all their nourishment from the air. Many of the plants are remarkable for the singular shapes of their flowers, which simulate various natural objects, insects, birds, reptiles, etc. So much so that Dr. Lindley says, "So various are they in form, there is scarcely a common reptile or insect to which some of them have not

been likened." Amongst our British genera we have the Fly Orchis (*Ophrys muscifera*), which presents the appearance of several flies growing up the stem; Bee Orchis (*Ophrys apifera*)

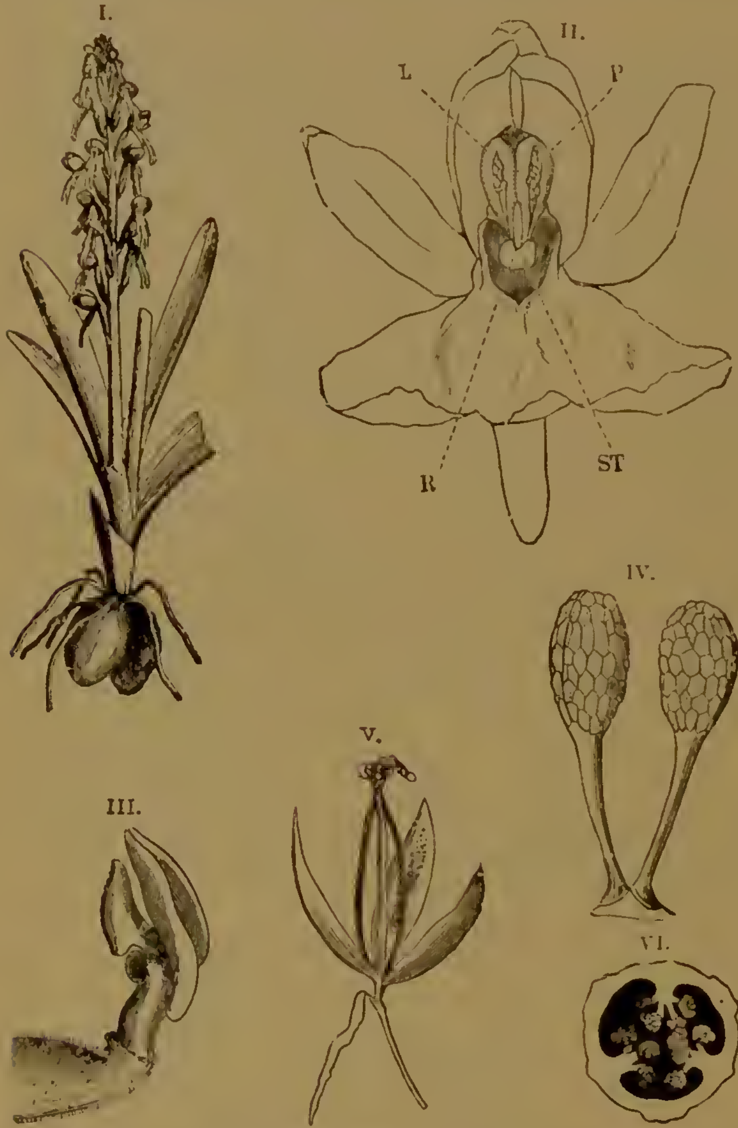

FIG. 314.—I. *Aceras anthropophora* (Man Orchid), whole plant. II. Flower of an Orchid looked at in front, the ovary being concealed: L, P, anther lobes, each containing a pollinium; ST, stigma; R, rostellum. III. Gynostegium of *Cypripedium*, seen laterally; above to the right the anther, to the left the stigma. IV. Pollinia of an Orchid, with their pedicels united by the rostellum. V. Burst capsule. VI Transverse section of an ovary.

and Spider Orchis (*Ophrys aranifera*), each with the flowers like the insects named. There are various species of the genus Orchis, all of which have spurred flowers: *Aceras*, or Man Orchid (Fig. 314, 1.); *Listera*, or Twayblade; *Habenaria*, or Butterfly Orchid, and others. Though so numerous a family, the plants are not economically useful. Salep is a starchy esculent substance obtained from the roots of several species of Orchis; and vanilla is a flavouring material obtained from the fruit of an exotic plant, *Vanilla aromatica*. The marvellous forms of the flowers cause them to be much cultivated in our greenhouses.

LILIACEÆ.

Typical plant, Bluebell (*Scilla nutans*, or *Agraphis nutans*).

Note, the plant is **herbaceous** (the Butcher's Broom is the only British plant which is shrubby, but exotics may be shrubs or trees); perianth **inferior, polyphyllous** (it may be **gamophyllous**), **six divisions** (in Herb Paris there are eight); **stamens six** (eight in Herb Paris); pistil **syncarpous, three-celled,** with **axile placentæ** and **numerous ovules** (four-celled in Herb Paris).

This large and important order is widely distributed throughout the world. It is divided into several sub-orders, some of which are sometimes raised to the dignity of orders.

The British genera may be grouped into the five following sub-orders:—

TRILLIDEÆ. Leaves net-veined; styles distinct; fruit a berry.

(All the other sub-orders have parallel-veined leaves.)

CONVALLARIEÆ. Fruit a berry; styles united; testa of seed membranous.

ASPARAGEÆ. Fruit a berry; styles united; testa of seed hard and black.

LILIEÆ. Fruit a capsule; styles united.

COLCHICEÆ. Fruit a capsule; styles distinct.

Principal British Plants.

TRILLIDEÆ.

Paris, Herb Paris. A remarkable plant with four net-veined leaves upon a short stem, and the parts of the flower arranged in fours, thus resembling Dicotyledons; but otherwise a monocotyledonous plant.

CONVALLARIEÆ.

Polygonatum, Solomon's Seal. Flowers axillary, drooping; perianth, gamophyllous, shortly six-cleft, tubular.

Convallaria, Lily of the Valley. Differs from last in flower-stalk being leafless; perianth campanulate.

ASPARAGEÆ.

Asparagus. Leaves small, subulate, surrounded by short scarious scales; flowers small, polyphyllous; two ovules in each of three cells of ovary; style single, and three-lobed stigma. The young succulent shoots are eaten.

Ruscus, Butcher's-broom. Shrubby plant. The branches

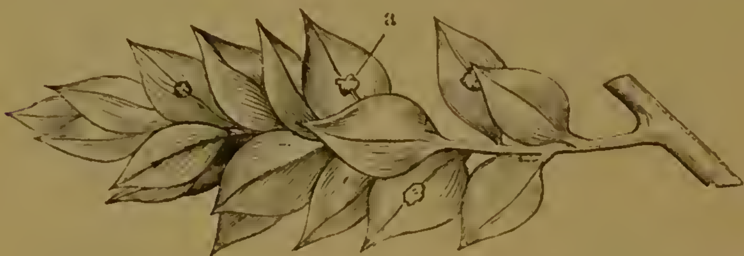

FIG. 315.—Leaf-like branch or phylloclade of *Ruscus aculeatus*: *a*, flower.

are leaf-like (Fig. 315), and known as **phylloclades**, the true leaves being scales upon them. The flowers are small, sessile upon the phylloclades.

LILIEÆ.

Allium, Garlic, Chives, etc. Flowers in an umbel, with two or three thin bracts at base; flower-stalk leafy. Amongst cultivated species of this genus are the Onion (*A. Cepa*), Garlic (*A. sativa*), and Leek (*A. Porrum*).

Fritillaria, Fritillary. Flowers generally single on the stalk, polyphyllous; the three inner segments have each a nectary at the base; anthers attached above their bases; style three-cleft.

Ornithogalum, Star of Bethlehem. Flowers in racemes or corymbs; perianth persistent; a scarious bract at base of each flower-stalk.

Scilla, Squill, Bluebell, etc. Flowers blue or pink, in racemes or panicles; perianth not persistent. The medicinal Squill is an exotic species of this genus.

Tulipa, Tulip. Flowers solitary on leafy stalk; petals without a nectary: anthers innate; style absent.

COLCHICEÆ.

Colchicum, Meadow Saffron. Flowers with long tube, so that the ovary is underground, but superior; styles three, very long and thread-like.

Amongst exotic plants of this order which are grown for ornamental purposes, or are variously employed, are several species of the genus *Lilium*, also *Hyacinthus*. The genus *Aloë* yields several species, some of which are used medicinally: *Dracæna Draco* is the famous Dragon Tree of Teneriffe; *Phormium* yields New Zealand flax; *Sanseviera* yields African hemp; the buds of the *Xanthorrhæa*, or Grass Tree of Australia, are eaten like Asparagus; and *Yucca* is the Adam's Needle.

AMARYLLIDACEÆ.

Typical plant, Lent Lily or Daffodil (*Narcissus pseudo-Narcissus*). Note the bulbous underground stem; membranous bract; perianth with **six divisions, superior**; corona (not always present in the order); **six** stamens, **epiphyllous**; ovary **inferior, three-celled.**

The plants of this order differ from the Liliaceæ in possessing an inferior ovary.

Principal British Genera.

Galanthus, Snowdrop. No corona; three outer segments of perianth larger than three inner; flowers solitary.

Leucojum, Snowflake. No corona; all perianth divisions equal; flowers two to six together.

Narcissus. Flowers with corona (Fig. 197).

GLUMACEÆ.

CYPERACEÆ.

Typical plant, Common Cotton Sedge (*Eriophorum polystachyum*, see Fig. 83).

Note, the stem is **herbaceous, solid**; leaves **sheathing**; the sheaths are entire, not split down the side of the stem opposite to the free lamina; flowers arranged in a spike with numerous scaly bracts (*glumes*), the outer of which are empty, and the inner ones contain the bisexual flowers; perianth

consists of numerous hypogynous bristles, which elongate on fruiting (in some plants of the order no perianth is present); stamens **three**; anthers **innate**; ovary **one-celled**, with three simple stigmas. This order contains numerous grass-like plants. In the large genus of Carex (Sedges) there are unisexual flowers (Fig. 317).

FIG. 316.—Flower of *Cyperus longus*, with the parts separated.

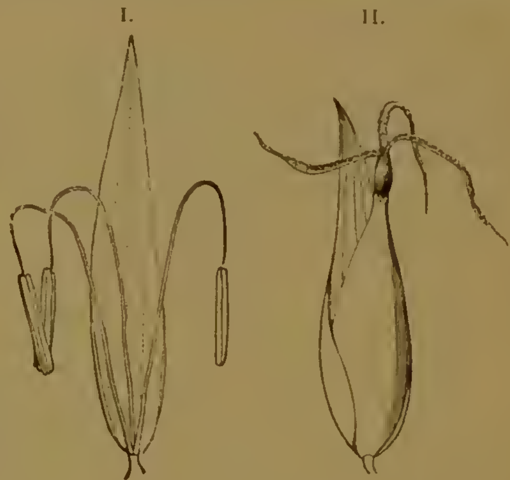

FIG. 317.—I. Male flower. II. Female flower of *Carex*.

The Sand Sedge (*Carex arenaria*) is very useful for binding together the loose sand by means of its creeping stems. The Lake Scirpus (*Scirpus lacustris*) is used for chair bottoms, baskets, mats, etc. Papyrus was obtained from the stems of an Egyptian *Cyperus*.

GRAMINACEÆ.

Typical plant, Common Wheat (*Triticum vulgare*).

Note, plant is **herbaceous** (some exotics are shrubby); leaves **sheathing**, sheath **split in front**; an appendage on the leaf where it separates from the sheath known as the **ligule** (Fig. 318, *a*); stem **hollow**, except at nodes.

Flowers arranged in a spike with glumes, as in Cyperaceæ. If we remove one of the spikelets from the centre of the spike (Fig. 319, I.) we find there are two outer bracts (**glumes**), G, G, containing several flowers, some fertile and others barren, FS. Each fertile flower is enveloped by two scales, one with a prolongation or **awn**, *a*, the flowering **glume**, or **outer pale**; the other, P*i*, more delicate, the **inner pale**. Within these there

are two minute scales, feathery above, the **lodicules**. These represent all there is of the perianth (see Fig. 319, II.); then three stamens with **versatile anthers**, and lastly a single ovary with **two feathery stigmas**.

This is the general structure of the plants of the order; there are, however, minor points of deviation. Thus, in the Sweet-

FIG. 318.—*a*, split leaf-sheath of a Grass; *b*, ligule; *d*, part of the lamina of the leaf; *c*, node of the culm.

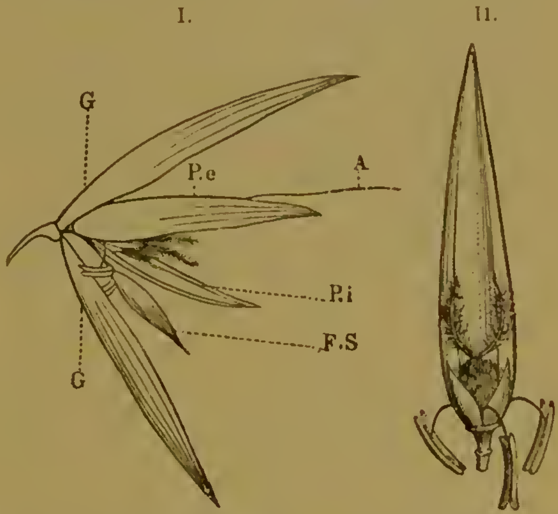

FIG. 319.—I. Expanded spikelet of the Oat, with a fertile and a barren flower, FS; G, glumes; *Pe*, outer pale, with awn, A; *Pi*, inner pale; within are the feathery stigmas. II. Fertile flower with the outer pale removed.

smelling Vernal Grass there are four outer glumes to each spikelet, in the Rye Grass one, and in the Mat Grass none. Sometimes the pale is absent, as in the Foxtail; or the lodicules, as in the Vernal Grass, Mat Grass, and Foxtail. In the Rice there are six stamens, and in the Mat Grass only one stigma. The Indian Corn has monœcious flowers; the staminate flowers have two lodicules and three stamens; the pistillate flowers no lodicules and but one stigma.

This large and wide-spread order is one of the most important to man, yielding, as it does, the various cereals that he employs as food, and the Grasses used as food for cattle. Amongst the cereals the first place must be given to Wheat (*Triticum vulgare*). The origin of this important plant is entirely lost in the past. We are not acquainted with the wild stock from which it has been produced. Numerous varieties of Wheat are cultivated, some with awns to the flowering glumes

and some without. Interesting experiments have been tried by Major Hallett in Sussex. By choosing the best ears and grains, and using these for sowing, and by repeating this process several times, the Wheat is greatly improved in character. By this process of artificial selection what is known as "Pedigree Wheat" is obtained. The seeds in the case of all the plants of the Gramineæ are albuminous, and flour is obtained from the crushed albumen.

Barley (*Hordeum vulgare*) is another important cereal, probably one of the first cultivated. Malt is prepared from Barley by allowing it to begin to germinate, and then heating it to 160° or 180°; by this means the starch of the grain is converted into sugar, which is capable of fermentation.

Oats (*Avena sativa*), Rye (*Secale cereale*), and Millet, which is obtained from several genera, are also cultivated. Indian Corn is obtained from *Zea Mais*, which is a native of the New World. Rice is obtained from *Oryza sativa*, a tropical plant.

Besides these food plants we have the important Sugarcane (*Saccharum officinarum*), the clarified juice of which yields us sugar, whilst the residue produces molasses and treacle.

Numerous Grasses are grown for fodder purposes, whilst from some sweet essences are obtained. Lemon grass oil is extracted from *Andropogon citratum*, citronelle oil from *Andropogon Nardus*, and some suppose that the spikenard oil of Scripture was obtained from *Andropogon Iwarancusa.*

The Bamboo is an arborescent genus of this order, used for many important purposes.

It will be well in conclusion to point out the differences between the two allied orders Cyperaceæ and Gramineæ in a tabular form.

Cyperaceæ.	*Graminaceæ*
Stem solid.	Stem hollow.
Leaf-sheaths entire.	Leaf-sheaths split.
No ligule present.	Ligule present.
No lodicules.	Lodicules generally present.
Anthers innate.	Anthers versatile.
Stigmas two or three, simple.	Stigmas almost always two, feathery.

PLAN FOR DESCRIBING A PLANT.

Root.—Kind.

Stem.—*a.* Kind (herbaceous, shrubby, or woody).
b. Shape (rounded, angular, square, ribbed, etc.).
c. Direction (upright, spreading, creeping, climbing, etc.).
d. Surface (smooth, hairy, rough, etc.).

Leaves.—1. Insertion (opposite, alternate, radical, etc.).
2. Petiole (presence or absence, peculiarities).
3. Lamina.
a. Composition (simple or compound).
b. Venation.
c. Margin.
d. Incision.
e. Apex.
f. General outline.
g. Surface (smooth, hairy, etc.).
4. Stipules (present or absent, shape if present; also note if sheath).

Inflorescence.—Kind of inflorescence and bracts.

Flower.—1. Calyx.
a. Cohesion (gamosepalous or polysepalous).
b. Number of sepals or divisions.
c. Adhesion (inferior or superior).
d. Specialities (colour, shape, etc.).
2. Corolla.
a. Cohesion.
b. Number.
c. Adhesion.
d. Specialities.
} As above.
Note. If perianth is present, describe it in same manner.
3. Corona or other appendages between corolla and andrœcium should be described here.
4. Andrœcium.
a. Cohesion (free, monadelphous, etc.).
b. Number.
c. Adhesion.
d. Specialities (if tetradynamous or didynamous; also peculiarities of filament and anther).

5. Gynœcium.
   a. Cohesion (syn- or apo-carpous).
   b. Number of carpels.
   c. Adhesion (inferior or superior).
   d. Peculiarities of ovary, including—
      α. Number of cells.
      β. Placentation.
      γ. Number of ovules.
   e. Peculiarities of style and stigma.

Fruit and Seed.

EXAMPLE.

SWEET VIOLET (*Viola odorata*).

Root.—Fibrous.

Stem.—Slightly shrubby, rounded, short, underground, forming a rhizome; surface scarred.

Leaves.—Apparently radical, but really growing in a tuft at apex of stem. *Petiole* evident, covered with short scattered hairs. *Lamina* simple, net-veined, unicostate, curve-veined, crenate margin, apex either rounded or somewhat acute, cordate or reniform, surface hairy, especially upon the margins and veins. *Stipules* present, slightly membranous, undivided, lanceolate.

Inflorescence.—Single-flowered, the flower-stalks growing from the axils of the leaves and bearing two small nearly opposite linear bracts about the centre.

Flower—

Calyx.—Polysepalous; five sepals, inferior, irregular, each sepal broad in centre and pointed towards the two extremities, green, hairy.

Corolla.—Polypetalous; five petals, hypogynous. Irregular, either purple or white; in the former case the lower petal has several darker lines converging towards interior of flower; the lateral petals have a hairy tuft near mouth of tube; the inferior petal is prolonged into a short blunt spur.

Andrœcium.—Stamens free, five in number, hypogynous, almost sessile, the filament being very short; connective prolonged beyond the

anthers as an orange-coloured mass; two of the stamens spurred, the spurs passing into the spur of corolla.

Gynœcium.—Syncarpous, three carpels, superior; ovary one-celled, with three parietal placentas and numerous ovules; surface of ovary hairy; style curved; stigma hooked.

APPENDIX I.

For the Cambridge local examinations the following orders are needed in addition to those in the body of the book :—for the Junior : Papaveracæ, Malvaceæ, Iridacæ. For the Senior : Violaceæ, Geraniacæ, Rubiaceæ, Dipsaceæ, Campanulaceæ, Ericaceæ, Solanaceæ, and Euphorbiaceæ. Also the life-history of a Moss, a Fern, and a Pine. For the Oxford Senior the life-history of Vaucheria, Mucor, and Saccharomyces. In this appendix we propose to deal with these, so as to make the work of greater use to those who are preparing for these examinations.

Grouping of the orders under their sub-classes :–

DICOTYLEDONS.

Thalamifloræ.

Pistil apocarpous.		Petals few, stamens many . .	Ranunculaceæ.
Pistil syncarpous	Parietal placentas	Stamens indefinite, sepals few	Papaveraceæ.
		Stamens tetradynamous, flowers cruciform .	Cruciferæ.
		Stamens 5, flowers irregular	Violaceæ.
	Free central placenta	. . .	Caryophyllaceæ.
	Axile placentas	Stamens free . .	Geraniaceæ.
		Stamens Monadelphous .	Malvaceæ.

Calycifloræ (see p. 153).

Corollifloræ.

Ovary inferior	Stamens epipetalous	Flowers simple, leaves verticillate		Rubiaceæ.
		Flowers compound	Stamens 4, separate	Dipsaceæ.
			Stamens 5, syngenesious . . .	Compositæ.
	Stamens epigynous	Herbs, milky juice, stamens 5 .		Campanulaceæ.
		Shrubs, stamens 8 or 10 . .		Ericaceæ. Tribe Vaccineæ.
Ovary superior	Placentas axile	Corolla regular	Ovary 4-celled — Stamens 5	Boraginaceæ.
			Ovary 4-celled — Stamens 8 or 10 . .	Ericaceæ.
			Ovary 2-celled . . .	Solanaceæ.
		Corolla irregular	Ovary 4-celled . . .	Labiatæ.
			Ovary 2-celled . . .	Scrophulariaceæ.
	Placenta free central			Primulaceæ.

INCOMPLETÆ.

Flowers not in Catkins	Calyx present, stamens opposite sepals, ovary 1-celled . . .	CHENOPODIOCEÆ.
	Calyx absent, leaves simple, ovary 2 or 3-celled	EUPHORBIACEÆ.
Flowers in Catkins . . .	Trees or Shrubs .	AMENTACEÆ.

PETALOIDÆ.

Perianth superior	Ovary 1-celled, flowers irregular		ORCHIDACEÆ.
	Ovary 3-celled	Stamens 3 . .	IRIDACEÆ.
		Stamens 6 . .	AMARYLLIDACEÆ.
Perianth inferior			LILIACEÆ.

GLUMACEÆ (see p 154).

THALAMIFLORÆ.

Natural Order PAPAVERACEÆ.

Plant for examination, Red Poppy.

Note that the plant is a herb. Break the stem across ; there exudes a milky juice, the latex ; (in some plants of the order the latex is coloured). The **leaves** are exstipulate. **Flowers** regular, **sepals** 2, very caducous (Fig. 168) ; **petals** 4, very deciduous, crumpled in the bud ; **stamens** numerous and distinct ; **pistil** 10 or more carpels (in the order there may be from two upwards), syncarpous. **Fruit**, a capsule with sessile stigmas and pores below (in the Chelidonium it is a siliqua). The order is found almost exclusively in the north temperate regions of both hemispheres. The two sepals and four petals distinguish it from all other British Thalamifloral orders, which have numerous free stamens. There are five British genera.

Chelidonium, the Greater Celandine. A common weed especially found near villages. It has a yellow latex, small yellow flowers, and a long narrow fruit resembling a siliqua.

Glaucim, the Yellow Horned Poppy. A plant common on the sea-coasts, especially of South Britain. It has large yellow flowers and long ovary, lengthening in fruiting, and provided with two stigmas.

Meconopsis, the Welsh Poppy. Found in Wales, Ireland, and some of the western counties of England. Flowers yellow, with an ovoid ovary and short style, and four to six stigmas.

Papaver, the various Poppies. The largest British genus, distinguished from all the rest by the numerous stigmas sessile on the ovary. The Opium Poppy is not a true native, but, having escaped from cultivation, has established itself in many parts. From this plant, cultivated in the East, the drug opium is obtained by cutting the capsule and drying the juice which escapes. The common Red Poppy is also used for medicinal purposes in making syrup of poppies.

Rœmeria, a rare plant, but established as a cornfield weed in

Cambridgeshire. It has pale purple flowers, with a long capsule; hence it is often called the Purple Horned Poppy.

The *Eschscholtzia*, so often found in our gardens, is a Californian plant of this order. Most of the plants of the order possess narcotic properties.

Natural Order VIOLACEÆ.

Plant for examination, Sweet Violet (see description, p. 186).

The plant is a herb, or slightly shrubby. **Leaves** stipulate. **Flowers** irregular; **sepals** 5; **petals** 5, irregular, one spurred; **stamens** 5, very short stalks, the connective prolonged beyond the anthers, two of the stamens spurred, the spurs passing into the spur of the corolla; **carpels** 3, syncarpous, one-celled, three parietal placentas with numerous ovules.

The genus **Viola** is the only one which is met with wild in Europe. There are several British species, including, besides the Sweet Violet, the Dog Violet and the Pansy.

In all the British plants, except the Pansy, the showy spring flowers are followed by the summer cleistogamous ones (see p. 132).

Natural Order GERANIACEÆ.

Plant for examination, Herb Robert.

The plant is a herb (in some exotic species there are low shrubs). The **leaves** are opposite (rarely alternate in the order), much divided (some plants in the order have undivided leaves), stipules present. **Flowers** regular (some plants have irregular flowers); **sepals** 5; **petals** 5; **stamens** 10, five of which are shorter than the others; **carpels** 5, united. **Fruit** 5-lobed schizocarp (Fig. 274).

The order is widely distributed throughout the globe; many of the plants are cultivated for the sake of ornament. The *Pelargoniums* of our gardens (often called Geraniums) are Cape plants of the order, whilst the *Tropæolum* (Fig. 167) comes from South America. There are four British generæ.

Erodium, Stork's Bill. Very much like the Geranium, but with only five stamens.

Geranium. There are several species of this genus. The Herb Robert is the commonest, being found throughout Britain, and flowering all the season. Other species are the Cut-leaved Geranium, the Dove's-foot Geranium, and the Meadow Geranium.

Oxalis, Wood Sorrel. Flowers regular, ovary not beaked, leaves ternate (Fig. 118).

This plant is supposed by many to be the original of the Irish Shamrock.

Impatiens, Balsam. Flowers very irregular, sepals and petals all coloured and usually made of six pieces. The Garden Balsam is a species from the East Indies.

Natural Order MALVACEÆ.

Plant for examination, the Common Mallow (Fig. 320).

The plant is a herb (in the order there are shrubs and trees). The **leaves** are alternate, stipulate and palmately veined. **Flowers** regular, showy, **sepals** 5, united; **petals** 5, twisted in the bud; **stamens** indefinite, monadelphous; **carpels** numerous. The order is a large one, widely distributed, but especially in tropical countries. Amongst exotic genera we find *Gossypium*, the Cotton Plant; *Hibiscus*, often grown in hothouses because of its handsome flowers; *Abutilon*.

There are three British genera.

Althea, the Marsh Mallow. Flowers with an involucre of five or more divisions. Like most of the plants of the order, it has a mucilaginous juice, which is used medicinally. The Hollyhock of our gardens is an exotic species from the Mediterranean coast.

Lavatera, Tree Mallow. Flowers with three distinct bracts. A very local plant, growing chiefly on the south and west coasts of England and Ireland.

Malva, flowers with three-lobed involucre. The true Mallows, of which there are three species.

COROLLIFLORÆ.

Natural Order RUBIACEÆ.

Plant for examination, the Cleavers or Goosegrass (Fig. 321).

The plant is a weak herb, climbing over bushes by means of the prickly hairs with which the stem and leaves are plentifully covered. **Leaves** apparently whorled, really opposite, with large well-developed stipules. **Flowers** small, regular; **calyx** superior, completely combined with the ovary without a visible border; **corolla** gamosepalous, rotate, four-lobed (in the order it is either four or five lobed); **stamens** 4, epipetalous (in the five-lobed flowers there are five stamens); **ovary**, single, with a two-cleft stigma. The plants of the order have, as a rule, very small flowers.

The order Rubiaceæ is very widely distributed; it is divided into three sub-orders. The Stellatæ, which is the only one found in Europe, has the leaves apparently verticillate by the growth of the stipules. The second sub-order is the Cinchoneæ, with opposite leaves, and a multilocular ovary and numerous seeds. The third is the Coffeaceæ, with opposite leaves and bilocular two-seeded ovary. Amongst the exotic plants of the order are the following: *Coffea*, which yields us coffee; *Cinchona*, which yields Peruvian bark and quinine: *Cephaëlis*, which yields ipecacuanha; *Bouvardia*; *Gardenia*.

There are four British genera.

Asperula, Woodruff and Squinancy Wort. Corolla with a distinct tube: calyx not distinct.

The Woodruff grows in woods and shady places; the Squinancy

FIG. 320.—*Malva sylvestris*: I. portion of plant (reduced); II. the monadelphous stamens (magnified); III. the pistil; IV. the fruit (natural size).

Wort is found in dry pastures, and on the hills of South England and Ireland.

Galium, various species of Bedstraw and Cleavers. Corolla rotate, no tube, four divisions.

FIG. 321.—*Galium aparine:* I. part of plant (natural size); II. flower and fruit (magnified); III. longitudinal section through fruit (greatly magnified).

Rubia, Madder. Corolla rotate, no tube, five divisions. The madder dye is obtained from the roots of a South European species closely related to our own Wild Madder.

Sherardia, Field Madder. Corolla with a distinct tube; fruit crowned by four calyx teeth.

Natural Order DIPSACEÆ.

Plant for examination, the Field Scabious.

The plant is a herb. **Leaves** opposite, exstipulate. **Flowers** in a head surrounded by an involucre, each flower in addition having at its base a small involucel, giving the appearance of an outer

calyx; between the flowers on the receptacle there are a number of hairs; **calyx** superior, five teeth; **corolla** gamopetalous, four-lobed (in some plants of the order it is five-lobed); **stamens** 4, epipetalous, anthers free; **ovary** one-celled with one pendulous ovule. The outer flowers of the head are much larger than the inner ones. The order is a small one spread in the temperate parts of the Old World. They are distinguished from the Compositæ by the stamens being four and free; from those Umbelliferæ which have their flowers in a head by the opposite leaves and gamopetalous corollas.

There are two British genera.

Dipsacus, Teasel. Provided with prickly scales between the flowers. The Fuller's Teasel has the spiny points of the involucral bracts recurved, and so is very useful in fullering. It is believed to have been produced from the common Teasel by cultivation.

Scabiosa, the various species of Scabious. Scales of the receptacle not prickly.

Natural Order CAMPANULACEÆ.

Plant for examination, Harebell. If this cannot be conveniently obtained, one of the garden Campanulas, or Canterbury Bells, will answer the purpose.

The plant is a herb, with alternate entire exstipulate leaves. The radical leaves, which usually die away when the plant is flowering, are orbicular or else cordate; hence the name of the plant, *Campanula rotundifolia*. The **stem-leaves** are narrow, lanceolate, or even linear. The **flowers** are regular (in some plants of the order they are irregular); **calyx** superior, with a free border of five teeth; **corolla** gamopetalous, campanulate (see Fig. 183, p. 107); **stamens** 5, inserted within the corolla at its base, but otherwise free from it; **ovary** three-celled, with three stigmas (in the order there may be from two to five cells in the ovary, and from two to five stigmas). The **fruit** is a capsule.

A rather large order widely distributed, especially in the temperate regions. It is distinguished from all other British gamopetalous orders, except the Ericaceæ, by the insertion of its stamens free from the corolla, not upon the tube. From the Heath family it is distinguished by the stems being herbaceous, and the stamens being the same number as the lobes of the corolla, never double the number.

There are four British genera.

Campanula, a large genus containing the various species of Canterbury Bell and Harebell. The plants have regular flowers, with the lobes of the corolla short and broad. Many exotic Campanulas are grown for ornament in our gardens.

Jasione, Sheep's Bit. Flowers in heads, surrounded by an involucre of bracts; corolla regular, divided into five long narrow segments, anthers united at the base into a ring.

The plant is widely distributed in England and Ireland.

Lobelia. Flowers irregular, anthers closely adhering. Found in the North and West.

Phyteuma, Rampion. Differs from Jasione in the anthers being perfectly free. There are two British species, neither of which is very common. The Spiked Rampion, with a spike of white flowers, only found at one or two places in East Sussex; the Round-headed Rampion, with a rounded head of blue flowers, only found on the chalk hills of South-East England, where it is fairly common.

Natural Order ERICACEÆ.

Plant for examination, Scotch Heath.

The plant is shrubby. **Leaves** small, whorled (in the order they may be alternate, opposite, or whorled). **Flowers** regular; **calyx** inferior, with four divisions (in the Vaccinums the calyx is superior, and there may be five lobes); **corolla** globose, with four teeth (Fig. 185, p. 107); **stamens** 8, free from the corolla; **ovary** four-celled. The stamens of this and of many other Heaths have peculiar awn-like appendages at the base of the anthers (Fig. 223, p. 117).

A large order spread over all the world except Australia. It is distinguished from all other British gamopetalous orders, except Campanulaceæ, by the stamens being free from the corolla, not on the tube; from the latter order, by the number of stamens being usually twice that of the corolla lobes, and the shrubby habit. The *Azaleas*, *Rhododendrons*, and *Kalmias* of our gardens are exotic genera of the order.

There are nine British genera, which are divided into two sub-orders.

Sub-order VACCINIEÆ. Ovary inferior, stamens epigynous.

Vaccinum. The only genus in the sub-order. It includes the Bilberry, Whortleberry, and Cranberry. The corolla is usually urceolate (Fig. 184, p. 107). The plants grow chiefly in boggy heaths and mountainous districts. Several species yield edible fruits.

Sub-order ERICEÆ. Ovary superior, and stamens hypogynous. Chief genera:—

Arbutus, Strawberry Tree. So called from its fruit, which, externally, somewhat resembles a strawberry, but is quite tasteless. Exotic Arbutus are often grown in our gardens.

Erica, Heath. A large genus known by the eight stamens and whorled leaves. The chief home of the Heaths is South-West Africa. The commonest British species are the Heather or Ling, the Scotch Heath, and the Cross-leaved Heath. Some Botanists put the Heather in a genus by itself, under the name of *Calluna.*

Pyrola, Wintergreen. Petals 5, distinct or slightly united at the base. Several species, which are found in damp woods, none of them very common.

Monotropa, Yellow Bird's-nest. A plant found in beech or fir woods. The whole plant is of pale brown or yellowish colour; the leaves are replaced by small scales. The plant is a parasite on the roots of the trees amongst which it grows, or else is a saprophyte feeding on the decayed leaves.

Natural Order SOLANACEÆ.

Flower for examination, Bittersweet Nightshade.

The plant is shrubby at the base. **Leaves** alternate. **Flowers** regular; **calyx** inferior, of five divisions; **corolla** gamopetalous, with five lobes, rotate (in the order the shape varies); **stamens** 5,

FIG. 322.—Henbane, *Hyoscyamus niger:* I. part of plant; II. capsule surrounded by the accrescent calyx; III. capsule (pyxis) (natural size).

alternating with the corolla lobes, anthers almost sessile; **ovary** two-celled, with numerous ovules. An order widely distributed in the Tropics. Most of the members possess narcotic properties, though many are used for food. Amongst exotic plants may be noted the Potato (*Solanum tuberosum*); Capsicums, which yield cayenne pepper; Tomatoes; Winter Cherry; Mandrake; Tobacco, and Petunia.

There are four British genera.

Atropa, the Deadly Nightshade. Corolla campanulate; fruit a berry. A very poisonous plant, found especially in South England. Used for medicine under the name of Belladonna (Fig. 176).

Datura, Thorn Apple. Corolla large, with a long tube; fruit, a prickly capsule.

A very poisonous plant, not truly native, but escaped from

cultivation, and has fixed itself in many parts of South England (Fig. 261).

Hyoscyamous, Henbane. Corolla obliquely campanulate; fruit, a smooth capsule. Another poisonous plant, sometimes used for medicine (Fig. 322).

Solanum, Bittersweet and Black Solanum. Corolla rotate; fruit, a berry. The Black Solanum is not so widely spread as the Bittersweet. Neither are so poisonous as the other plants of the order.

Natural Order EUPHORBIACEÆ.

Plant for examination, Caper Spurge (*Euphorbia Lathyris*), or other Common Euphorbia.

The plant is a herb, with an acrid juice (Latex). **Leaves**

FIG. 323.—Euphorbia Lathyris.

simple, opposite (in most Spurges they are alternate). **Flowers** arranged in monœcious bunches; each bunch (Fig. 323, II.)

has an involucre with 4 or 5 teeth, and looking very much like a calyx; within this, crescent-shaped glands, alternating with the teeth of the involucre (in some Spurges the glands are not crescent-shaped); in the centre several male flowers, each consisting of a single stamen jointed to a stalk with a scale-like bract at its base (Fig. 323, III.); one female flower consisting of a three-lobed three-celled ovary, supported upon a curved stalk, which gradually lengthens until the ovary hangs out of the involucre; the fruit splits up into three separate carpels, each with a single seed (in some plants of the order there are two seeds in each), with an **arillus** on the top.

Amongst exotics of the order there are shrubs and trees, and one shrub, the Box, is found in this country. The plants of the order are most variable in their structure, and are mostly found in tropical regions.

Three British genera—

Buxus, Box. Shrubs with shining evergreen leaves; male and female flowers distinct, with calyx present. *Buxus Sempervivens*, the Common Box, is the only British species. The wood is used for engraving and other purposes.

Euphorbia, Spurge. Herbs with several male and one female flowers, surrounded by a perianth-like involucre. Several species.

The Poinsettia of our greenhouses is an exotic Euphorbia.

Mercurialis, Dog's Mercury. Herbs with thin leaves; male and female flowers separate, and with a calyx present. Two British species.

Amongst exotics are: *Croton Tiglium*, which yields Croton oil; *Croton Elateria*, yielding Cascarilla bark; *Ricinus Communis*, the Castor-oil plant; various species of *Hevea*, yielding Para India-rubber; *Manihot Utilissima*, yielding Cassava Meal, Brazilian Arrowroot, and Tapioca.

Natural Order CORYLLACEÆ.

In the Cambridge syllabus is the same as the sub-order Cupuliferæ, of the order Amentaceæ (see p. 176).

MONOCOTYLEDONS.

PETALOIDEÆ.

Natural Order IRIDACEÆ.

Plant for examination, Yellow Flag.

The plant is a herb. **Flowers** large and showy; **perianth** superior, with petal-like segments; the three inner ones are smaller than the outer ones; **stamens** 3; **ovary** inferior, three-celled, with many ovules; **stigmas** 3, enlarged and petal-like (Fig. 233).

A rather large order, especially met with in South Africa and

other dry, warm countries. It differs from the Amaryllidaceæ in having three (not six) stamens.

There are five British genera. The chief are—

Crocus. Rootstock bulbous, with very long perianth tube. Two species, the Spring and the Naked Crocus. The colouring-matter saffron is obtained from the stigmas of the Saffron Crocus.

Gladiolus. Perianth with six nearly equal segments. Only found wild in the New Forest and the Isle of Wight; perhaps an escape from cultivation. Our garden Gladiolus are exotic species.

Iris. Yellow Flag and Fœtid Iris. Outer segments of the perianth larger than the inner; stigmas petaloid. Both species are abundant. Many exotic species are cultivated for the beauty of their flowers.

LIFE-HISTORY OF PINUS.

We may take the Scotch Fir (*Pinus sylvestris*) as the example of the genus. It is a tree that grows to a considerable size; the main trunk is simple or forked, and has a reddish bark. It is

FIG. 324.—Transverse section through a mature resin-passage of *Abies Excelsa*; the cavity *Hg*, as well as the thin-walled cells *Hp*, are filled with a semi-fluid resin, while the thick-walled compressed cortical cells P still contain small quantities of starch. (× 800.)

provided with two kinds of leaves. First, there are the green foliage leaves, which are long and needle-like (Fig. 120); secondly, the scale leaves, which are small and brown. If we take a branch of the Fir in the early spring—about the end of March—we find that at the end there is a bud, which is covered over with these brown scales. In the axil of each of these scales there is a small bud. Beneath the terminal bud there are two similar but smaller

buds, also covered with scales. When the terminal bud grows, it produces the elongation of the stem; the side buds produce the whorled branches which appear on the stem. This elongation will have taken place by the end of May; and now the stem is provided with pale-coloured shoots a few inches long. On these there are a number of buds, which are seen to spring from the axils of the scales, which still persist, although much separated from one another. Each of these buds consists of a very small branch, with two foliage leaves enclosed in the enveloping scales. As this little bud grows, the axis remains small, but the leaves elongate until they form the well-known fir-needles. We often speak of the short axis as a **dwarf shoot.** Other species of Pine have a varying number of leaves on the dwarf shoot—two, three, or five; but in the *Pinus sylvestris* there are always two. The general structure and growth of the stem is similar to that which we have described as being met with in the Dicotyledons. The chief differences are that there are no vessels, that the thickened cells are chiefly those with bordered pits, and that there are very characteristic resin-passages (Fig. 324). The root-system is similar to that met with in Dicotyledons. The needle-shaped leaves are flat on the upper surface, rounded below. Along each edge there is a ridge, which makes the leaf feel somewhat rough to the touch. It follows that a section, instead of being flat like that of most leaves of flowering plants, is semilunar. The epidermal cells have thick walls, and those at the corners are especially large, forming the ridges already noted. The guard cells of the stomata are placed some little distance below the surface of the leaf. Beneath the epidermis there is a narrow band of thick-walled cells. It varies in thickness from a single layer to several layers of cells. This is known as the **hypoderma.** It consists of thick schlerenchyma cells, and is absent beneath the stomata. Beneath this is the mesophyll, made up of thin-walled chlorophyll-containing cells. There is no loose tissue of stellate cells. There are several resin-passages in it.

FIG. 325.—Pinus Sylvestris-staminate flowers (natural size).

There are two central vascular bundles, in structure like those of the stem. They are surrounded by a pericycle of colourless cells, and outside this and separating it from the mesophyll is a layer of oval cells, the endodermis or bundle-sheath.

The flowers are monœcious. The staminate flowers replace the dwarf shoots in some of the lower scale leaves of which we have spoken. By May or June they are fully developed and form a spiked inflorescence, the axis growing through produces a number of dwarf shoots above. Each flower consists of an

elongated axis, with a number of stamens arranged in a spiral manner around it. Each stamen (Fig. 219) has a short filament, and above an anther with two pollen sacs with longitudinal dehiscence. Within are the pollen grains, which are provided with wing-like expansions, which render them very light and easily carried about by the wind (Fig. 249). Before pollination the cell divides into two, a large and a small cell. The pollen-tube is produced from the larger cell, the smaller one appearing to represent what we shall have to call the prothallus in the Fern. The pistillate

Fig. 326.—Larch (*Pinus Larix*): I. a seed-scale *b* from a young cone, seen from the inner side, with the bract *a*, and the two inverted naked ovules *d*; II. ripe cone; III. a scale *a* from a ripe cone, seen from the outer side, *b* the bract which has not grown along with the scale, and is therefore smaller; IV. the seed *b* with its wing *a*; V. longitudinal section through the seed, the small embryo *k* lying in the endosperm *e*.

flowers appear at the end of the lateral branches. At first they are small dark buds, and appear to be terminal. When, however, they develop, they are found to be really lateral near the end of the shoot. Each flower consists of an axis, around which there are a number of membranous scales which are fringed at the edge. These are known as the bract scales. Upon each of these there is another, the seminiferous scale, which, at first small, soon becomes larger than the bract scale. At the base of each of the seminiferous scales there are two ovules. Each ovule is surrounded by a single integument instead of two, and is not enclosed in an ovary or other receptacle. The large micropyle points downwards.

There is much uncertainty as to the real relation of these parts to those of ordinary flowering plants. Some botanists regard each seminiferous scale as a separate flower, and the whole cone as an inflorescence ; others look upon the so-called bract scale as a flat carpellary leaf, and the seminiferous scale as a placenta, and the whole cone as one flower. (For an account of the fertilisation of the Pinus, see pp. 127 and 128.) The ripe cone of the Pinus (Fig. 154) consists of a number of woody scales arranged spirally. At the lower part of these there are two seeds. Each seed has a single coat or testa, within which there is a fleshy endosperm with a straight embryo at one end near the micropyle. The embryo is provided with a number of cotyledons arranged in a whorl (Fig. 44). Although called cotyledons, they are really the first leaves of the plant formed underground. Since the Pine and its allies have their seeds naked, unprotected by any fruit, they are spoken of as Gymnosperms, or naked-seeded plants. All other flowering plants are known as Angiosperms, or enclosed-seeded plants, since they have their seeds enclosed in a fruit. We can thus divide the great sub-kingdom of Phanerogams, or flowering plants, as follows :—

Phanerogams.

Gymnosperms. **Angiosperms.**

Dicotyledons. **Monocotyledons.**

The order of the Gymnosperms to which the Pinus belongs is known as the **Coniferæ**, or cone-bearing order. The Scotch Pine, the Yew, and the Juniper are the only truly British plants of the order. Amongst exotic plants we have the various species of Pine and Spruce. The *Araucaria*, or Monkey Puzzle ; the *Sequoia*, the gigantic tree of California ; the Firs, Larches, and Cedars ; the Cypress ; the *Thuja*, or Arbor Vitæ. The order is widely distributed, although in the tropics it is chiefly to be found in the mountainous districts. Deal wood is obtained from species of Fir, and turpentine is furnished by various Pines. There are one or two other orders belonging to the Gymnosperms, which are not represented by British plants.

LIFE-HISTORY OF A FERN.

We may take the Male Fern, *Aspidium Filix-mas*, one of the commonest of all the British Ferns, as the specimen for our examination. It has a thick rootstock, rising in the mature plant above the ground, which is provided at its apex with a rosette of tall leaves. The surface of the stem is completely hidden by the dead bases of the former year's leaves, and also by a number of brown scales, or **ramenta**. These ramenta also clothe the lower part of the leaf-stalk. A transverse section of the stem shows a very different arrangement to that which we met with in the flowering plants. There is on the outside an epidermis made up

of small cells, their walls being of a yellowish-brown colour, and with slightly thickened walls. Beneath this there is the sclerenchyma, several layers of thick dark brown cells with thickened walls. The greater part of the stem is taken up by the ground tissue, large rounded cells with thin walls, which are pitted. These cells contain much protoplasm and starch. There are numerous intercellular spaces in the ground tissue. Within the ground tissue there are a number of fibro-vascular bundles arranged in an irregular ring. Outside the ring of bundles there are a number of isolated ones, which are the branches going out to the leaves. Each bundle consists of a bundle of sheath, or endodermis, a layer of very thin-walled cells, the phloëm sheath, or pericycle, varying in thickness at different parts of the bundle. At the ends of the oval bundle it is somewhat thin, but at the sides it is much thicker. The phloëm comes next, consisting of sieve-tubes and bast fibres or protophloëm, together with parenchymatous cells. The xylem occupies the centre of the bundle, and contains large scalariform tracheides (Fig. 33), with parenchymatous cells in between. Such a bundle is called concentric, and is very characteristic of Ferns. If a longitudinal section is made of the stem the bundles will be seen to run out into the leaves by means of branches which spring off from the main cauline or stem bundles. The roots come off from all parts of the stem, and are brown and much branched. In section the root is seen to be surrounded on the outside by the piliferous layer, brown cells, many of which grow out to form root hairs. Beneath this there is the general parenchyma of the root, the walled pitted cells without starch-grains. Next there is a ring of sclerenchyma—brown, thick-walled cells, many layers thick. Below there is the endodermis—a single layer

FIG. 327.—Stem of *Aspidium Filix-mas.*

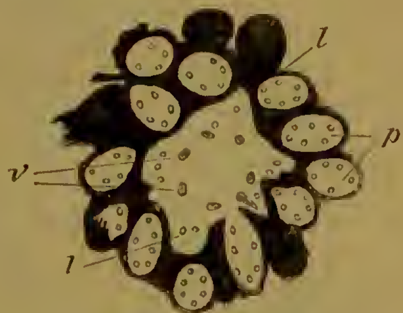

FIG. 328.—Transverse section of the stem of *Aspidium Filix-mas.* *p*, petioles; *v*, vascular bundles of the cylindrical network; *l*, bundles passing out to leaves and roots.

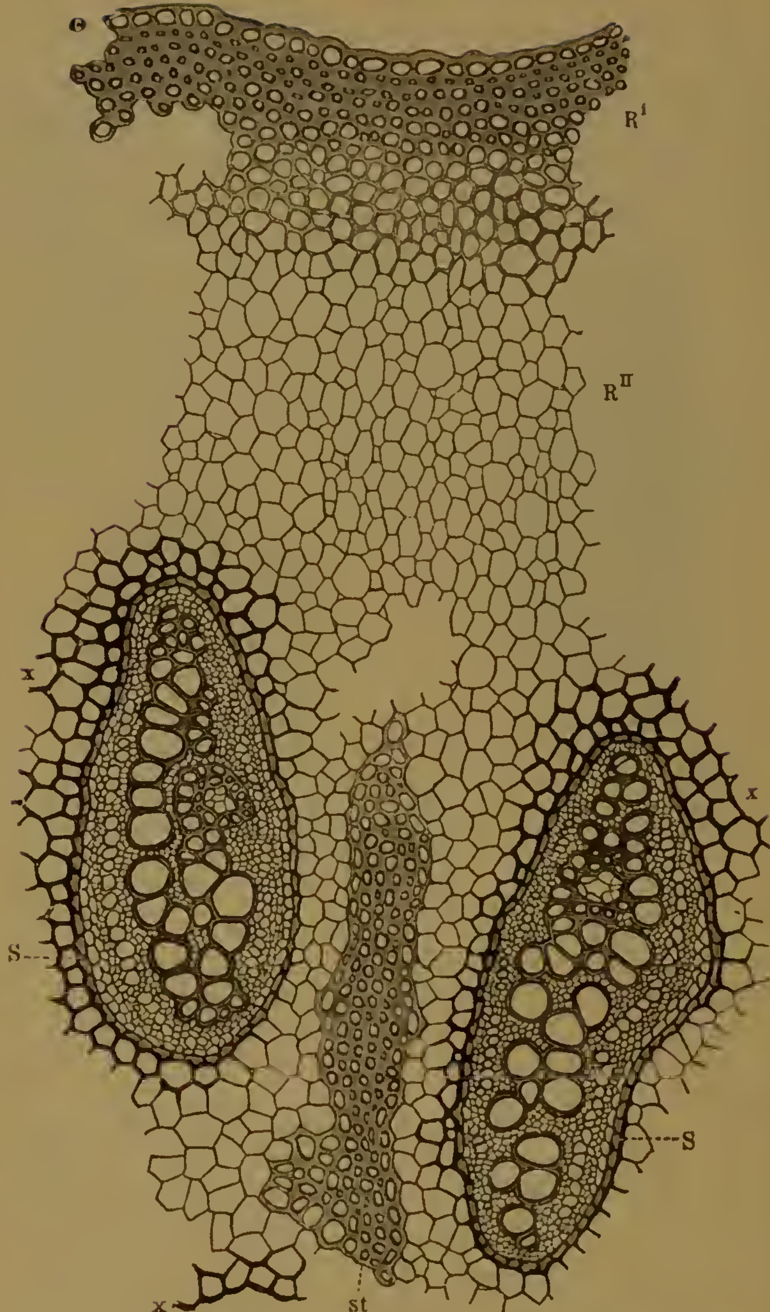

FIG. 329.—Transverse section through the rhizome of the common brake, *Pteris aquilina*: *o*, epidermis; R′ thick-walled, R″ thin-walled cortical tissue; S, vascular bundle-sheath; *x*, sclerenchymatous cells outside the latter; *st*, bundles of prosenchymatous cells (× 110).

of flattened cells, often very difficult to see owing to the walls being pressed out of shape. The pericycle comes next. This consists of one or two layers of thin-walled parenchymatous cells with protoplasmic contents. The xylem consists of two groups of various-sized trachëides, the largest being towards the centre of the root. At first the two groups are quite distinct, and lie on the outside of the bundle close to the pericycle, but as the root gets older they develop inwards until they meet in the centre. There are two groups of phloëm, which alternate with the xylem, and consist

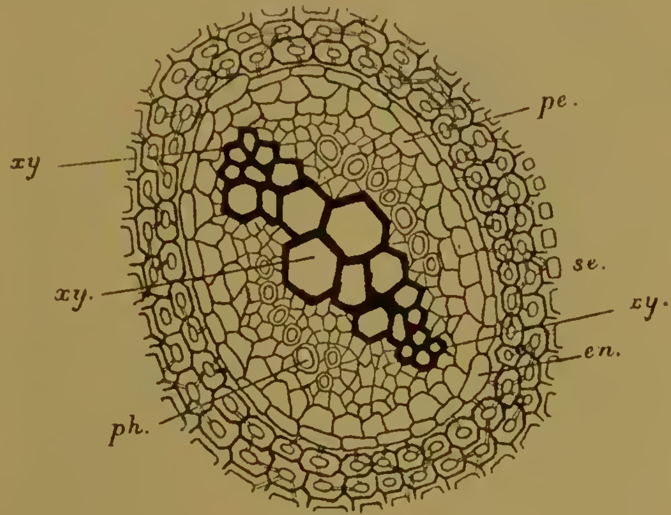

FIG. 330.—Transverse section through the central cylinder of a root of *Aspidium Filix-mas*: *se*, sclerenchyma; *en*, endodermis; *pc*, pericycle; *ph*, phloëm; *xy*, xylem.

chiefly of sieve-tubes. At the apex of the root, in the place of the numerous cells of the growing point of the root of flowering plants, there is a single apical cell, which, by its division, produces the various tissues of the root.

The leaves grow in a rosette at the end of the stem. If we examine the young leaves, we find that they have a circinate vernation. The young leaves are entirely covered with the brown scales, or ramenta. On examining the fully developed leaf, we find that it has a long petiole, or leaf-stalk. Running up on each side of the stalk there are lateral ridges or wings, rather lighter in colour than the rest of the stalk, which is somewhat brown. The blade is bipinnate. The venation is forked, each vein branching in a bifurcated manner. The general microscopic structure of the leaf is similar to that which we have described as being found in flowering plants (p. 71). On the under side of the leaves will often be seen some small round brown bodies. Each of these is known as a **sorus** (plural **sori**). They are arranged in a double line on either side of the central vein of each pinnule. Each sorus is covered by

a thin reniform piece of membrane—the **indusium**. On removing this, we lay bare the reproductive organs below. Each of these consists of a spore-case, or **sporangium** (plural **sporangia**). The sporangia grow from a little swelling on the leaf, the placenta, from which the indusium also springs. Each sporangium consists of a stalk with a rounded head or capsule. On the margin this has a ring of flattened cells, the **annulus**, which projects beyond the rest. When the sporangium is ripe and bursts, this annulus straightens itself, and thus causes the opening of the capsule. Within the sporangium are the **spores**. Each of these consists of a single cell with a brown wall, which is double. The outer layer, the exospore, is corky and is much corrugated ; the inner wall is thinner.

FIG. 331.—Leaf and sori of *Aspidium Filix-mas.*

These spores, when they grow, do not at once develop into a fern. If they are sown upon damp earth, or, better still, peat or rich vegetable soil, and are kept from the direct sunlight, they will soon begin to grow. The exospore bursts ; the endospore, or inner wall, is protruded in the form of a filament ; this divides, at first transversely, so as to form a string of cells, then longitudinally, so as to produce a flattened, leaf-like expansion, the **prothallus**. This is somewhat reniform ; at the base of the depression on the margin is the growing point. On the under side there are given off several root-like threads, the **rhizoids**. The cells of the prothallus are one layer thick, except in the central part, which is usually thicker than the rest, and is called the **cushion.** The colour of the prothallus is green from the presence of chlorophyll in the cells. On the under side of the prothallus are the sexual organs, which are of two kinds: the **antheridia**, or male organs, and the **archegonia**, or female organs. Each antheridium is hemispherical outgrowth of the prothallus, and is situated at the hinder part of the under surface, amongst the rhizoids. It consists of a wall, made of a single layer of narrow cells ; within there are a number of smaller cells, the mother-cells of the antherozoids. The **antherozoids** or **spermatozoids** are spiral masses of protoplasm produced from the nuclei of the mother-cells. At one end they are provided with cilia, by means of which, after having escaped from the antheridium, they can move rapidly in the water. The archegonium is situated, as a rule, on the cushion of the prothallus. Each consists at first of three cells. The cell

which lies next to the prothallus divides, to form a hollow mass of cells sunk in the prothallus, and containing the **oosphere.** The cell furthest from the prothallus divides into four rows of cells, forming the neck. The cell between these two divides into three. The **oosphere** sunk in the prothallus, the ventral canal cell just above it, and the neck canal cell between the cells of the neck.

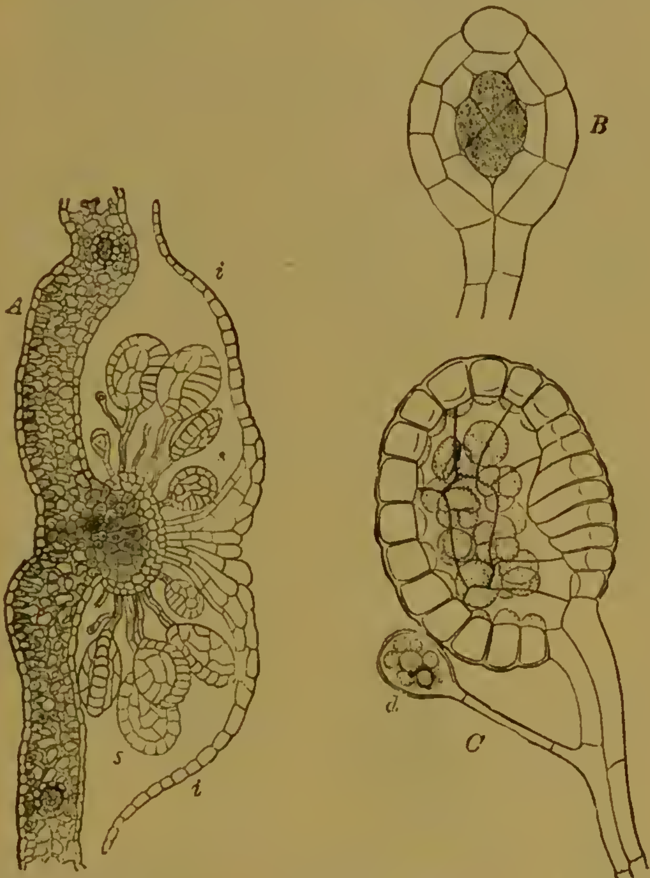

FIG. 332.—*Aspidium Filix-mas.* *A*, section through leaf and sorus; *s*, sporangia; *i*, indusium: *B*, young sporangium; *C*, mature sporangium containing spores; *d*, glandular hair. (Sachs.)

When the archegonium is quite ripe, these canal cells are converted into mucilage, the antherozoids pass up the neck and fertilise the oosphere. This now forms the **oospore,** which quickly divides into eight cells. One of these grows down to form the first root. Two more grow into the prothallus, forming the foot, which absorbs nourishment for the young Fern. Two others develop into the first leaf, or **cotyledon.** One forms the growing point of the stem. The

other two do not develop at all. Thus from the prothallus a Fern is produced which resembles the original one. We have here an

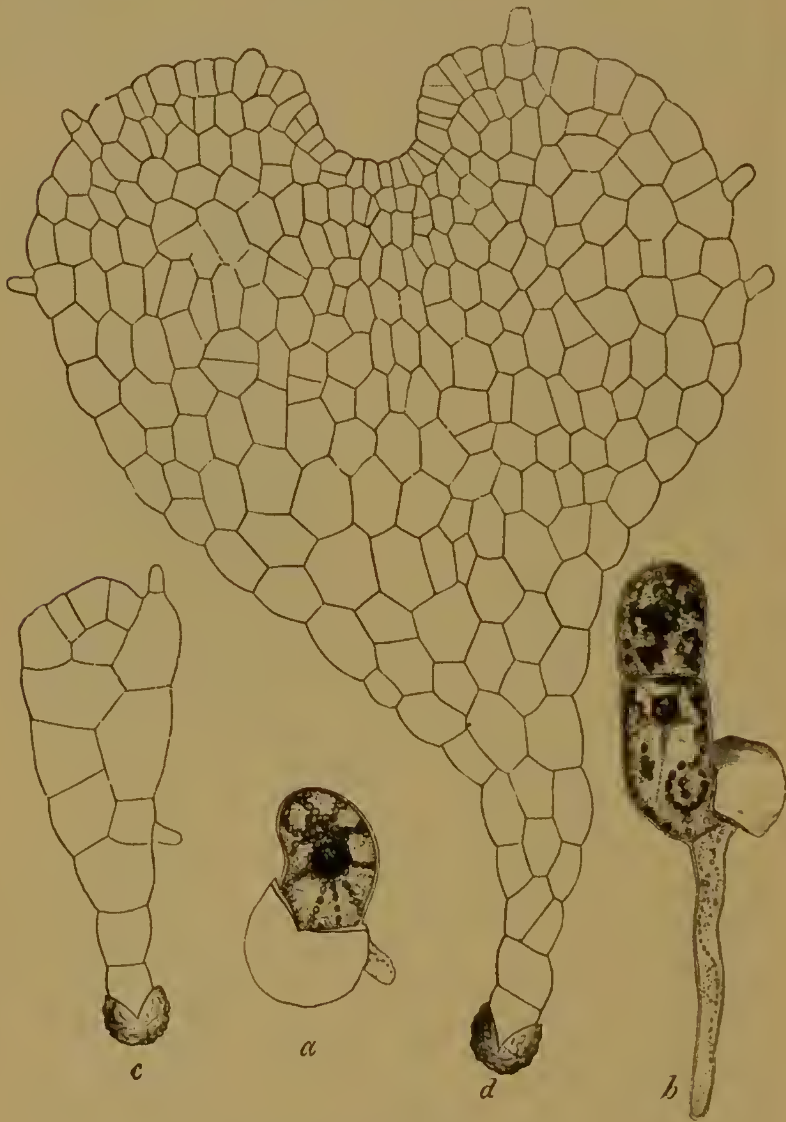

FIG. 333.—Germination of a fern spore. *a*, *b*. *Dicksonia antarctica*; *c*, *d*, *Aspidium Filix-mas*. (Luerssen.)

example of what is known as alternation of generations. The ordinary Fern produces a prothallus, which in its turn develops an

ordinary Fern. The prothallus is spoken of as the **oophyte**, or egg-bearer; the Fern plant, as the **sporophyte**, or spore-bearer. The

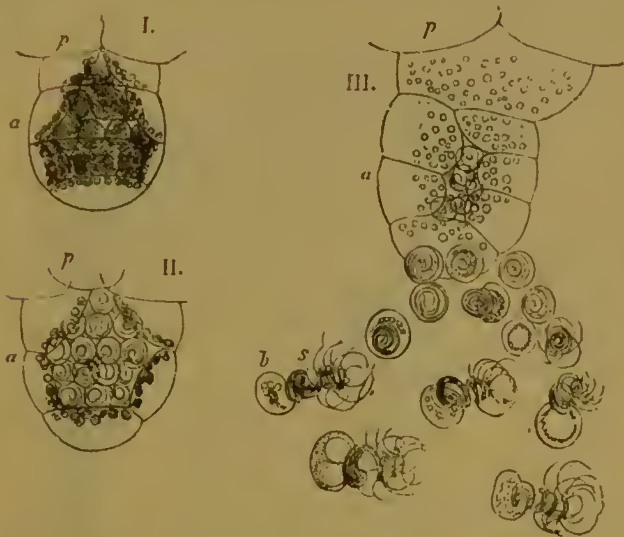

FIG. 334.—Antheridia of *Adiantum capillus-Veneris* in different stages of development. *p*, prothallium; *a*, antheridium; *s*, antherozoids; *b*, vesicle with starch-grains.

description given refers especially to the *Aspidium Filix-mas* (*Nephrodium Filix-mas*, as it is often called). There are little

FIG. 335.—Archegonia of *Aspidium Filix-mas*. A, young; B, nearly mature; *o*, oosphere; *v.c.*, ventral canal-cell; *n.c.*, neck canal-cells. (After Hofmeister.)

differences in detail in other ferns. Some ferns have diœcious prothali; antheridia and archegonia growing separately. The Ferns are placed in a group of the flowerless plants known as **Filices**. The characters of the group are that the plants have fibro-vascular bundles, the spores are all the same size, and the sporangia are arranged in sori.

LIFE-HISTORY OF A MOSS.

We may take the Hair Moss, *Polytrichum commune*, or else the *Funaria hygrometrica*, as an example for examination. The plant is a small herb with a short erect stem, and small simple leaves arranged

Fig. 336.—Hair-moss, *Polytrichum commune*: I. plant with sporangium (magnified); II. sporangium with calyptra; III. without calyptra (magnified); IV. plant with perigonium surrounding the antheridial receptacle, and exhibiting prolification (magnified); V. antherozoid (× 1000).

at the base. Below there is a dense mass of rhizoids of a brown colour, which grow down into the soil. At the top of some of the

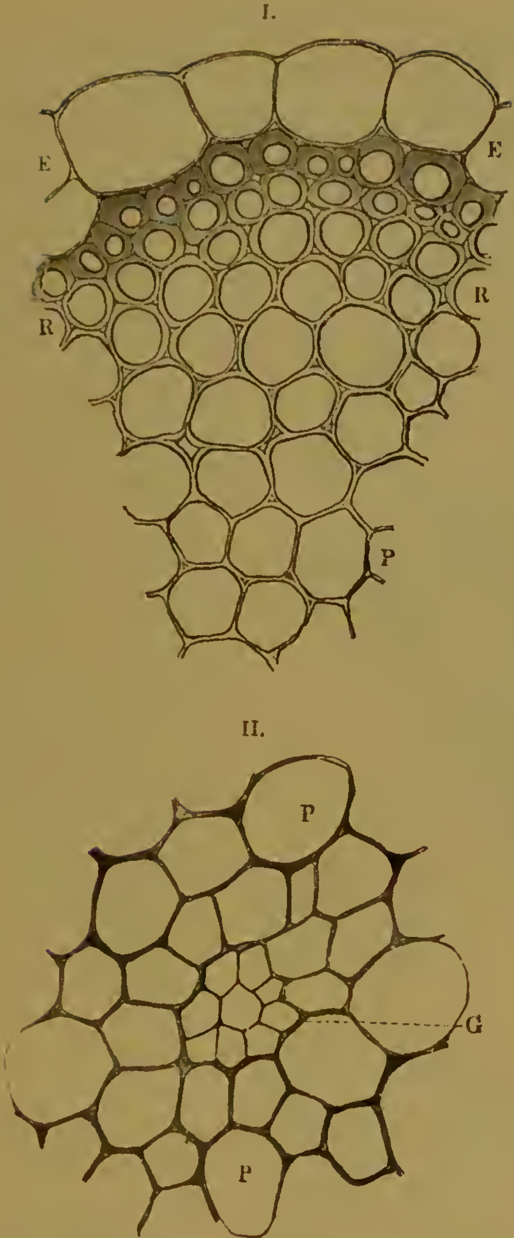

Fig. 337.—I. Part of a transverse section through the stem of *Sphagnum cymbifolium*; E, epidermal cells; R, thickened and coloured cortical cells; P, parenchyma of the stem (× 320); II. central portion of a transverse section through the stem of *Climacium dendroides*; G, central axis; P, brown parenchyma of the stem (× 400).

stems there is a little bud. In other cases there is a rosette of leaves, the **perigonium**, which surrounds the reproductive organs. Although, for the sake of convenience, we have spoken thus of the stem and leaves of the Moss, we must remember that they are not to be compared with the stem and leaves of the Fern. The ordinary Moss plant is the oophyte, and thus is the representative of the Fern prothallus. The stem is very simple in structure, and has no true fibro-vascular tissue. There is a thin epidermis; beneath this some thickened schlerenchyma cells with red walls, forming a cortex. Then there are a number of cortical cells, with thinner walls and starch-grains. In the centre there is a mass of yellowish cells, which may be looked upon as forming the rudiments of a fibro-vascular bundle. The leaves are very small and simple. They have no stomata, and in the centre of each a mass of cells forming a rudimentary vein.

The sexual organs grow on different plants (*diœcious*). The male plant has the **antheridia** placed at the apex of the stem, surrounded by the perigonal leaves. Each antheridium is white and club-shaped, and between them there are often a number of green threads, the **paraphyses**. Each antheridium has a short stalk and a swollen, club-shaped body, which consists of a wall one layer of cells thick, enclosing a large number of cells, which are the mother-cells of the antherozoids. When ripe these mother-cells escape from the antheridium as a thick, mucilaginous mass. This mucilage dissolves in water, and the **antherozoids**, which are in structure much like the antherozoids of the fern, escape, propelling themselves by means of the cilia. The **archegonia** are situated on separate plants, each one being surrounded by a perigonium and paraphyses. Each archegonium consists of a swollen basal part, the **venter**, and a long narrow **neck**, the whole filled by the canal cells, whilst in the venter below is the **oosphere**. The mouth of the neck is closed by four lid cells. When the archegonium is fully developed, the canal cells are converted into mucilage, which swells and forces off the lid, and the antherozoids, entering, fertilise

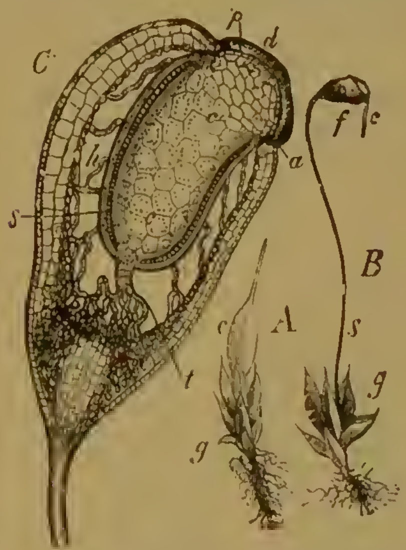

FIG. 338.—*Funaria hygrometrica. A*, leafy axis, with root-hairs, and young sporogonium enclosed in the calyptra, *c*. *B*, nearly mature sporogonium; *s*, seta; *f*, urn-case or capsule; *c*, calyptra. *C*, longitudinal section of capsule (magnified); *cc'*, columella; *d*, epercurum; *p*, peristome; *s*, layer in which the spores are developed, consisting of the spore mother; cells; *h*, air-cavities; *t*, filamentous tissue of the columella. (After Sachs.)

the oosphere. This becomes the **oospore**, and develops into the sporophyte, which, however, does not grow as a separate plant. The oospore divides into an upper and a lower cell. The lower one, by repeated division, forms a stalk, or **seta**; the upper one produces a **theca** or **sporogonium**, or spore-capsule.

The seta, growing down into the stem below, obtains nourishment from it. At first the venter grows with the sporogonium, which is contained within it; but finally it ruptures, and the upper part is carried up by the ascending sporogonium as a little cap, or **calyptra**, whilst the lower part forms a **vaginula**, or sheath, at the base (Fig. 336 II.).

At first the capsule is a mass of small cells. Soon, however, a differentiation begins amongst them. Those in the centre form a solid mass, the **columella**; outside this there is a layer of tissue formed, the **archesporium**, from which the spores are produced. This is in turn surrounded by an air-cavity, which separates it from the walls of the capsule. The air-cavity is traversed by a number of thin threads of green cells, which suspend the columella and archesporium. The lower part of the capsule, known as the **apophysis**, is often more or less swollen (Fig. 338).

The top of the theca comes off as a lid, or **operculum**. When removed, the mouth is seen to be closed by a number of curved teeth, the **peristome** (there are sixty-four in Polytrichum, and thirty-two in Funaria). These, on opening, aid in the scattering of the spores.

The archesporium consists of two or three layers of cells, forming the spore-sac; and within this a single layer of cells, which by division produce the spore mother-cells. Within each of these, by free formation, from **spores** are formed. The spore, in growing, produces a long green filament, the **protonema**, from which the Moss plant is produced by means of buds.

We have here again an alternation of generations. The theca is the sporophyte, and the ordinary Moss plant the oophyte. The two are not separated, but remain together during life.

In the Fern the sporophyte is the larger and more important stage; in the Moss the oophyte is the larger.

LIFE-HISTORY OF VAUCHERIA.

There are several species of this Alga. They are of interest, as it was the examination of one species, *Vaucheria clavata*, in Vienna, by Unger, in 1826, which led to the discovery of protoplasm by Von Mohl. They grow in wells, springs, ditches, on damp soil, and on the soil of pots in greenhouses.

They form a green, tangled, felt-like mass, where usually the separate fibres can easily be distinguished by the naked eye.

Examined under a microscope, Vaucheria is seen to consist of long, branched, tubular threads. These are not divided into separate cells, there being only one cavity for the whole length of

the tube. Staining shows, however, that there are a number of nuclei. After the nucleus has divided, no cell wall is produced, the nuclei lying free in the protoplasm. Such a cell is often spoken of as a **cœnocyte.** The protoplasm lines the cell wall, and contains several chloroplasts, whilst a sap vacuole fills the centre. From various parts of the filament, branches, destitute of chlorophyll, are

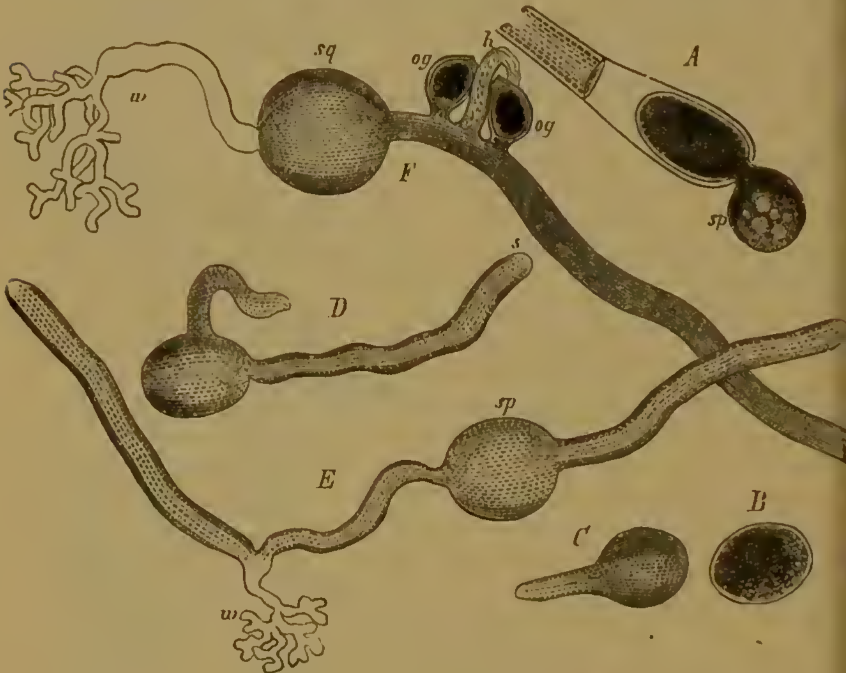

FIG. 339.—*Vaucheria sessilis* (× 30). *A*, a zoogonidium (*sp*) escaping; *B*, zoogonidium in its resting stage, after having lost its cilia; *C*, zoogonidium germinating; *D*, further stage in the germination; *E*, germination still further advanced; *sp*, the zoogonidium; *s*, apex of the tubular green thallus; *w*, rhizoids, root-like colourless portions of thallus; *F*, thallus with reproductive organs; *h*, antheridium; *og*, oogonia. (After Sachs.)

given off which fix the plant to the substratum. These, which are not true roots, are spoken of as rhizoids.

There are two methods of reproduction.

Asexual is by means of **zoogonidia,** or **swarmspores.** These are formed soon after dawn, or they can be observed by keeping the vaucheria in a saucer of water in the dark until just before the time of observation. The extremities of some of the filaments swell up and become club-shaped and filled with dark, densely aggregated protoplasm. This club-shaped **zoosporangium** becomes cut off by means of a septum from the rest of the filament. The apex of the cell thus formed is ruptured and the protoplasm is protruded (Fig. 339, *A*). It escapes from the cell by a streaming movement, whilst

at the same time the whole mass rotates in a screw-like manner, and, since the slit through which it passes is narrow, it is constricted during its passage, assuming an hour-glass-like shape. Frequently it is severed into two, forming two zoogonidia. At other times only one zoogonidium escapes from the cell.

Each zoogonidium, or swarmspore, is an oval mass of proto-

FIG. 340.—*A*, *C*, and *D*, *Mucor mucedo*; *A*, sporangium in optical longitudinal section; *C*, zygosphore; *z*, *k*, germ-tube; *g*, sporangium; *D*, conjugation; *B*, *Phycomyces nitens*; *m*, mycelium; *g*, sporophore. (Brefeld.)

plasm, consisting of a firmer outer layer, the **ectoplasm**, and an inner mass, the **endoplasm**, which contains chloroplasts and several minute nuclei. The surface is covered with cilia, and by their movement the zoogonidium is propelled rapidly through the water.

Finally it comes to rest, the cilia are withdrawn, a cellulose coat is formed, and **resting spore** is produced (Fig. 339, *B*).

This germinates, giving off two branches, one which is sometimes colourless, produces the rhizoids, the other which is green produces the branching filaments (Fig. 339, *C*, *D*, *E*, *F*.

Sexual Reproduction is by means of **antheridia** and **oogonia** (Fig. 339, *F*, *h*, *og*).

Each antheridium arises as a little outgrowth from the filament, containing chloroplasts and several small nuclei. The chloroplasts sink to the lower part of the outgrowth, which is cut off from the upper part, forming a stalk. The upper part, the true antheridium, is destitute of chlorophyll, and is curved over, forming a hook-like process. From the nuclei **antherozoids** or spermatozoids are formed, which are motile by means of cilia, and are liberated by the rupture of the apex of the antheridium. The **oogonium**, like the antheridium, commences by an outgrowth; this is cut off from the filament by a short stalk. In shape the oogonium is rounded, with a short, beak-like process at the extremity. The beak bursts, and some of the protoplasm is extruded. The remainder aggregates around the nucleus, forming the **oosphere**. This is generally dark coloured, with many chloroplasts and oil globules, but at one point, near the beak, there is a clear spot, the **receptive spot**. A spermatozoon enters, the open beak passes into the receptive spot and fuses with the nucleus of the oosphere. The latter forms a cellulose coat around itself and produces an **oospore**, which, after a period of rest, germinates into the ordinary plant.

Mucor Mucedo.

The White Mould, a plant which makes its appearance on a variety of damp substances. If a piece of bread be moistened and covered over with a glass, after a few days it will be probably covered with white fleecy threads forming a kind of felt-work. Some of these will rise up from the general mass, and are seen to be terminated by little knobs like pin-heads. This will probably be some species of Mucor, of which *Mucor Mucedo* is the most common. On examining with the low power of a microscope, it is seen to be made up of a large number of tangled threads, forming what is known as the **mycelium**. The individual threads are called **hyphæ**. Some of them grow down into the bread or other substance on which the mould lives; these are spoken of as **submerged hyphæ**; others, **aërial hyphæ**, rise up above the mass of the mycelium, and many of them have the rounded, knob-like heads.

In structure the hypha is a cell; the wall, however, differs from that of ordinary cells in that it is not stained blue by Schultze's solution; the material of which it consists is spoken of as **fungus cellulose**. The rounded prominences on the aërial hyphæ are the **sporangia**, or spore cases. Each sporangium (Fig. 340, *A*) is a rounded cell into which the end of the hypha enters, being closed at the extremity and forming the **columella**.

The wall of the sporangium is beset with numerous crystals of **Calcium oxalate.**

The protoplasm of the sporangium becomes formed into a number of rounded unicellular **spores.** When ripe the sporangia burst and the spores are scattered. Being extremely light, they are easily carried by the wind, and on falling upon a suitable substance, such, for instance, as damp bread, they germinate, each of them growing out to form a fresh hypha.

This method of reproduction is asexual.

Having no chlorophyll, Mucor cannot decompose the carbon dioxide of the atmosphere. It is not, however, like the Broomrape and Dodder, a parasite, feeding upon the sap which has been elaborated by a living plant. It feeds upon dead substances. Such a plant is said to be a **saprophyte.**

It will live very well in what is known as **Mayer's solution,** a solution of sugar, ammonic nitrate, potassic phosphate, calcic phosphate, and magnesium sulphate. In this case it takes its carbon from the sugar, and its nitrogen from the ammonium nitrate. It will also grow well in **Pasteur's solution,** in which ammonic tartarate replaces ammonic nitrate. It can even obtain its nitrogen from organic nitrogenous compounds such as pepsin. If pepsin be caused to replace the ammonium compound in Pasteur's solution, Mucor will thrive well in it. The food enters the cell by osmosis, and is built up into the tissue of the mould.

Besides the ordinary asexual method of reproduction, there is in Mucor, under certain circumstances, a sexual method. Two neighbouring hyphæ, or two neighbouring parts of the same hypha, give off branches, **gametes,** which gradually approach one another. A division wall appears in each branch, cutting off the apical portion from the main hyphæ. The two apical portions come together (Fig. 340, *D*), the wall between them becomes absorbed, and they fuse together and form a round **zygospore.** This is spoken of as a process of **conjugation.** The zygospore possesses two coats; an outer, **exospore,** dark, with warty protuberances; an inner, **endospore,** much thinner and more delicate. The zygospore remains for several months in a resting condition. Finally, however, it germinates; the exospore bursts; the endospore grows out as a simple, delicate hypha, which, instead of branching and forming a complex mycelium, at once gives off an aërial hypha with a sporangium and spores (Fig. 340, *C*), which germinate in the ordinary way.

Saccharomyces, Yeast.

Yeast has long been known as a substance capable of producing fermentation. If a little brewers' yeast be examined with the naked eye, it presents the appearance of a brownish soft substance. Examined with a hand lens it is seen to be granular in structure. Placed under the high power of a microscope it is found to consist of a number of cells (Fig. 4) of varying sizes, but usually varying from 0·0003 to 0·0005 of an inch in

diameter. Some of the cells are quite separate from one another; others are arranged in rows, whilst in many cases smaller cells may be seen budding from the larger ones. Each cell is a true yeast plant. It has the usual cell structure, cell wall, protoplasm, and vacuole, but no nucleus is present. The cell wall, like the cell wall of Mucor, consists of fungus cellulose, and is not stained blue by Schultze's solution. Like Mucor, Saccharomyses will grow well in Mayer's or in Pasteur's solution. Multiplication takes place by budding. A protuberance is formed upon one part of the cell wall, this increases in size, and is finally cut off from the main cell. Often by this means strings of yeast-cells are formed. No sexual method of reproduction is known in connection with Yeast.

One of the most important facts with regard to the life of Torula is its power of setting up fermentation. If a little yeast is placed in a liquid containing sugar, such, for instance, as Mayer's or Pasteur's solution, and is kept at a temperature of from 25° to 30° C., the sugar gradually disappears, alcohol and carbon dioxide being produced.

The first effect is to convert cane sugar into grape sugar—

$$\underset{\text{Cane Sugar.}}{C_{12}H_{22}O_{11}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Grape Sugar.}}{2C_6H_{12}O_6}.$$

Next the grape sugar is broken up into the alcohol and carbon dioxide—

$$\underset{\text{Grape Sugar.}}{C_6H_{12}O_6} = \underset{\text{Alcohol.}}{2C_2H_6O} + \underset{\text{Carbon Dioxide.}}{2CO_2}.$$

If the saccharine solution and yeast are placed in a small flask fitted with a cork through a hole in which a bent tube passes, the other end of which dips into a glass of lime water, the presence of the carbon dioxide can be shown by the lime water becoming thick and milky. A small portion of the sugar yields carbon for the growth of the yeast; a little more is broken up into glycerine and succinic acid; but by far the largest amount is thus decomposed into alcohol and carbon dioxide. A substance which can thus bring about a change in the substratum in which it lives is spoken of as a ferment. In the production of Beer, Yeast is added to an infusion of malt; the malt sugar present, which is closely allied to grape sugar, is broken up in a similar way.

APPENDIX II.

PRACTICAL WORK.

CHAPTER I.

SEEDS.

(Read pages 3-5, 141-143.)

Material required:—Seeds of the following plants—Broad Bean, Pea, Gourd, Sunflower, Mustard, Castor Oil, Pansy, Marvel of Peru, Wheat, Maize, and any others that can be obtained.

1. Soak some seeds of **Broad Bean** in water for twenty-four hours. Note—

a. The general shape (oval or kidney shaped).

b. The surface of a brown colour, and usually more or less wrinkled.

c. At one side a scar, the **hilum**. This marks the point of attachment of the seed to the fruit.

d. Squeeze the seed, and a drop of water is found to ooze out from a hole at one end of the **hilum**. This hole is the **micropyle**.

e. A ridge is seen to run from near the micropyle along the edge of the seed (the **raphe**).

f. Make a sketch of the seed showing all these parts (Fig. 1).

g. With a sharp penknife cut a slit along the edge of the seed opposite to the hilum and then remove the seed-coats. In the Bean the two coats (**testa**, or outer, and **tegmen**, or inner, are firmly attached together).

h. Examine the **nucellus**, or **kernel**, which is left when the coats are removed. Note that it consists of a large fleshy mass (the **cotyledon**), evidently divided into two, and a small pointed portion (the **radicle**) on one side.

i. Note the position of the radicle with relation to the micropyle, and make a sketch of the complete kernel.

j. Carefully separate the two **cotyledons** along the edge opposite to the radicle so as not to remove them from that organ; and between them note above the radicle a little bud (the **plumule**) bent over. Examine with a lens and sketch the opened kernel.

These three parts, **cotyledons, radicle,** and **plumule**, form the **embryo** from which the future plant will grow.

2. Soak some **Peas** in water, and repeat the above observations, making sketches of all that you do.

In both the Bean and the Pea the cotyledons are very thick and fleshy ; they contain the food that the young plants require in the beginning of their growth. Compare with these the seeds of the Oak (Acorn) and Almond, which also have fleshy cotyledons.

3. Soak some **Gourd** seeds in water, and note the following points.

a. The seeds are oval and flat. At one end there is a scar, the hilum. Besides it there is the micropyle, which can be found by squeezing the moistened seed.

b. Carefully remove the leathery seed-coat. Note that the inner coat, the tegmen, is quite separate from it, and is much thinner. Remove this.

c. Note the flat, white embryo, with the small pointed radicle towards the micropyle, and the large, flat cotyledons. Sketch.

d. Separate the cotyledons ; the plumule between is very small and is hardly apparent until the seed begins to grow. Sketch.

4. Soak some **Sunflower** "seeds" in water. The so-called "seeds" of the Sunflower are really the fruits (achenes), containing the true seeds.

a. In shape they are somewhat oval, pointed at one end, which is the base, and flattened at the other, which is the apex. On the flattened apex there is a scar ; the remains of the style and stigma.

b. Remove the outer fruit wall. Within is a single seed with a very thin seed-coat, and the radicle pointed to the base of the fruit. Sketch.

c. Remove the seed-coat and separate the cotyledons. Between there is the small plumule. Sketch.

5. Soak some seeds of **White Mustard** in water, and note—

a. They are small and round ; there is a small scar showing the hilum. Sketch.

b. Remove the seed-coat ; the two thin cotyledons lie flat against one another, the radicle being placed along the line that separates them (see Fig. 285). Sketch.

c. Separate the cotyledons, and note the small plumule between. Sketch.

In the Gourd, Sunflower, and Mustard, the cotyledons are much less fleshy than in the Bean and Pea. In all these seeds the embryo entirely fills the seed. They are **exalbuminous.**

6. Soak some seeds of **Castor Oil** plant in water. Note—

a. The seed-coat is hard, bright, and mottled. At one end there is a wart-like swelling. The **arillus.** Sketch.

b. With a sharp knife remove the seed-coat. The kernel within is white and oily. Note that it is covered by

a thin inner coat, the tegmen which is easily removed. The oily mass which forms most of the kernel is the **endosperm**, the embryo being within.

c. Carefully slit the endosperm parallel to its broad sides. Within is the embryo consisting of a small pointed radicle, two thin cotyledons, and a small plumule between. Sketch. We have here an **albuminous** seed with central embryo surrounded by peripheral albumen (see Fig. 289).

7. Soak some **Pansy** seeds in water and examine. These seeds are very small, but with a hand lens a similar structure to that of the last can be made out. An arillus at one end, and if the seed be cut longitudinally, the central embryo. Sketch.

8. Soak seeds of **Mirabilis** (Marvel of Peru) in water.

Here, as in the case of the Sunflower, the so-called "seeds" are really the fruits. Note—

a. The whole is covered with a rough brown coat which is the persistent perianth. The apex is pointed and the base is flattened.

b. Remove this. Within is the true fruit covered with a light brown coat, which is the pericarp with the seed-coat within. At the base there is a white scar which marks the position of the hilum, at the other end a small swelling shows where the style was attached. Through the thin brown coat the position of the inner parts can be made out, especially the radicle which curves over towards the hilum. Sketch.

c. Remove the thin coat, and the radicle is seen bent over on one side with the two cotyledons on the other. Make a section through the kernel, and the perisperm will be found in the centre surrounded by the peripheral embryo (see Fig. 290). Sketch.

In all the seeds examined so far there are two cotyledons present. The plants belong to the group of **dicotyledons**.

9. Soak some grains of **Wheat** in water, and examine.

The grain of Wheat is the fruit containing the seed.

a. Note the shape, oblong with one side convex and the other flat, with a deep longitudinal groove; at one end on the convex side there is a small oval mark. This shows the position of the embryo. Close to this there is either a small hole or a short stalk marking the attachment of the fruit to stem. Sketch in two or three positions to show these parts.

b. Cut the grain in two along the groove, taking care to bisect the embryo, and examine with a lens. Note the outer skin which consists of the coats of the fruit and the seed-coat. The greater part of the seed made up of the mealy **albumen**. The **embryo** at the base consisting of the single **cotyledon** placed against the albumen, the **radicle** pointing towards the base of

the seed and above the **plumule** (see Fig. 3). (It is well to examine with a lens a prepared and mounted microscopic slide of a grain of Wheat.) Sketch. (See Fig. 46.)

10. Soak some grains of **Maize** in water, and repeat the above observations. In both of these cases we have **albuminous** seeds with the embryo lateral, *i.e.* placed by the side of the endosperm (see Fig. 291). They are also examples of the group of **monocotyledons**, there being only one cotyledon present in the embryo.

11. Examine any other seeds in the same way, making out if they are albuminous or exalbuminous, dicotyledons or monocotyledons. Make sketches of all the seeds you examine.

CHAPTER II.

GERMINATION.

(Read pages 26–31.)

For the purpose of germination the seeds should, as a rule, be soaked in water before sowing. Some should be placed in damp sawdust, and others sown in earth in pots. It is well to sow the seeds at intervals of a few days, so as to have the young plants in various stages of growth for the purpose of comparison.

1. **Broad Bean** seeds. Soak in water for twenty-four hours, then place in the wet sawdust or earth, and cover over with a piece of tile. Keep warm and moist, and examine from day to day.

At first the seed swells and the seed-coats split towards the micropyle ; the radicle is protruded, being pushed out of the seed by the elongation of that part of the stem which is situated below the cotyledons (the **hypocotyl**). The root formed by the radicle lengthens, growing downwards. It forms a single central root, stout above and tapering below (**tap-root**). After a short time the plumule begins to come out from the seed and grow upwards. If the covering tile is removed so as to expose the young plant to the light the plumule soon becomes of a green colour. From the upper part of the root lateral branches are seen to arise (see Fig. 48). The cotyledons, as a rule, cast off the seed-coats and often become greenish in colour, but they do not rise above the soil and become leaf-like. Finally they gradually wither away. As the plumule lengthens forming the young stem we note that leaves are given off from certain parts (the **nodes**), the stem between forming the **internodes**. At the first node there is given off a pair of leaves opposite to one another, and at right angles to the cotyledons. These leaves are very simple in their structure, and consist of only one piece. The second node bears only one leaf, which is divided into three leaflets. Make sketches of the plant at various stages of its germination.

2. **Moisture** is needed for germination. Place some Bean seeds in dry sawdust and keep in a warm place. No germination will take place.

3. **Heat** is needed for germination. Treat some seeds as in 1, but keep in a cold place. No germination occurs.

4. Treat **Peas** as in 1; watch their germination from day to day, and compare with what happens in the case of the Bean. Note—

a. The cotyledons remain within the seed-coats, they do not come out or turn green.

b. The hypocotyl is not so long as in the case of the Bean.

c. The first simple leaves do not come off in pairs. Make sketches showing these points.

5. Place soaked **Sunflower** "seeds" in damp sawdust, and examine as they germinate. Note—

a. The radicle is protruded from the micropyle, and grows down into the soil.

b. The hypocotyl lengthens, growing upwards out of the soil, forming a loop joining the root with the cotyledons, which are still within the fruit beneath the ground.

c. The loop increases until soon the fruit is drawn above the ground, when it splits open and the cotyledons emerge and become green, forming the first pair of leaves.

d. The plumule rising between the cotyledons grows up into the stem with leaves. Note the arrangement, and compare with that seen in the cases of the Bean and Pea. Make sketches of the various stages.

6. Repeat these experiments with seeds of **Gourd** and **Mustard**, comparing with the Sunflower and making sketches.

7. Repeat the experiments with **Castor Oil** seeds. Note that whilst the cotyledons here also rise up and form green leaves, they do not emerge from the seed until all the endosperm has been absorbed by the growing plant. In all cases compare the cotyledonary leaves with the foliage leaves of the same plant in point of structure. Make sketches of everything observed.

The above experiments are examples of the germination of dicotyledonous plants.

8. Repeat the experiments with grains of **Wheat** and **Maize**. In many cases the radicle is directly prolonged, but it does not branch much or attain a very great length; very soon fresh roots appear from higher up, either from the hypocotyl or even from the base of the plumule (**adventitious roots**). These grow out from the seed, giving the appearance of two or three roots issuing side by side (Fig. 47). The plumule rises above the ground, and unfolds the first leaves. The single cotyledon remains within the seed, absorbing the food contained within the endosperm. Sketch the germinating seeds in two or three stages of their growth.

CHAPTER III.

ROOTS.

A.—Structure and Growth.

(Read pages 30–34.)

Material required:—Young seedlings of Broad Bean, Pea, Gourd, Wheat, Maize, and other convenient plants. Roots of Carrot, Radish, Turnip, Dahlia, Lesser Celandine, various Orchids, and any other plants that can be conveniently obtained.

1. Examine a seedling of **Bean** or **Pea**. Note—
   a. The radicle is prolonged into a single stout primary root (tap-root).
   b. Numerous branches are given off from the upper part. These secondary roots are arranged in an **acropetal** order, that is, the oldest are nearest the base, and the youngest nearest the apex of the primary root. These branches, like the primary root, grow downwards into the soil.
   c. In an older plant these in their turn give rise to branches.
   d. There are no leaves or any other organs growing upon the roots.
   e. On the last portion of the primary root there are no branches.
   f. There is no arrangement into nodes and internodes, as we have seen in the young stem.
   g. When the young plant is taken up from the soil a quantity of earth or of the sawdust is found to be clinging round the apex. Carefully clean this away by means of water and a camel's-hair brush. The root near its apex presents a silky appearance. Examine with a pocket lens. It is due to minute **root-hairs** which are not present on the older parts of the root, but are plentiful on the younger parts near the apex (see Figs. 43 and 52). Make a sketch showing these points.

2. Examine and sketch roots of **Carrot**, or **Beet** (conical, Fig. 53), **Radish** (fusiform, Fig. 54), and **Turnip** (napiform, Fig. 55).

3. Examine and sketch any other specimens of tap-root that can be conveniently obtained.

4. Examine a young plant of **Wheat**, **Maizo**, or some **Grass**. Note there is not a single tap-root, but a large number of thin fibres (**Fibrous root**, Fig. 56).

5. Examine the roots of a **Buttercup**, and compare with the Wheat. The roots here also are fibrous; but whilst in the Wheat the fibres are branched, in the Buttercup they are quite simple. Sketch.

6. Examine the roots of the **Dahlia**, **Lesser Celandine**, or of some **Orchid**, *e.g.* Early Purple or the Spotted Orchis. Whilst the roots are fibrous, several of the fibres have swellings upon them (**Tuberous Roots**. Figs. 57, 58, and 59). Sketch.

Growth of Root.

7. Take a germinating Bean with a root some two or three centimetres long. Make carefully upon it several marks two millimetres apart, the first some two or three millimetres from the tip, and others at various parts of the root. Suspend with the root hanging in the upper part of a jar half filled with water so as to keep it moist for growth. Examine after about twenty-four hours. The marks nearest to the tip will be found to be the most separated from one another, those a little further up the root are less separated, and those at the base are not separated at all. Sketch. *The most rapidly growing part of the root is just behind the tip.*

B.—Functions.

(Read pages 34–39.)

Material required :—Plants for observation of absorption of water, Germinating Peas, Platinum foil, Spirit lamp or Bunsen burner, Culture solution, Jars, Apparatus for osmosis, Slab of Marble, Turnip or Carrot root.

1. Take three complete **plants**, that is, plants with root, stem, and leaves. Weigh number one carefully, and place it on a sheet of paper in the sun. Place number two through a hole in a piece of cardboard, so that its roots can hang down into some water in a glass, and mark the height to which the water rises in the glass. Place number three in some earth in a flower-pot, taking care to keep it well watered. Invert glass vessels over numbers two and three, and keep them in the sun. Plant number one will soon become limp and withered. Weigh it, and note how much it has lost in weight. Plants numbers two and three will remain fresh. At the same time the water in the vessel containing number two will be lowered, and the interior of the glasses placed over numbers two and three will be found to be covered with moisture. Number one is withered because it has lost water : in the other two cases the water lost by the plant has been replaced by that taken up by the root. *Living plants lose water which is being continually taken up by the root.*

2. Take four germinating **Peas** or other convenient seeds that have a well-developed tap-root, and place them in four vessels of water so that number one has the whole root immersed, number two the root as far as the root-hairs, number three only the tip below the root-hairs ; number four is bent over so that the root above the root-hairs is the only part immersed. Numbers three and four will wither, whilst the others will remain fresh. *It is by means of the root-hairs that the root absorbs water.*

3. Place a drop of **distilled water** upon a piece of glass or platinum, and evaporate carefully over a spirit lamp or Bunsen

burner. No stain is left behind. Repeat the experiment with a drop of spring or tap water. There is a stain left due to substances from the soil dissolved in the water. *These dissolved substances are of importance as food for the plant.*

Water Culture.

For the purpose of water culture wide-mouth bottles are required, with corks fitted. When a seed has been well germinated in damp sawdust, a notch is cut in the cork, to receive it, so that the root can hang down into the liquid within the bottle. It is well to cover the outside of the bottle with black paper, to protect it from the light. Various solutions are used for water culture, but the following will be found to answer very well.

In a litre of water (distilled) dissolve the following: Potassium Nitrate, 1 gram, Sodium Chloride, Calcium Sulphate, Magnesium Sulphate, and Calcium Phosphate, of each ½ a gram. It is well to boil the solution for at least half an hour, replacing the water that evaporates. A drop or two of a solution of Ferric Chloride is to be added. The bottles are to be thoroughly cleaned, being rinsed out with acid, and afterwards with distilled water, till all trace of acid is removed. If there is any difficulty in fixing the seeds, they may be kept in their places by means of soft asbestos recently burnt. It is well to have a glass tube through a hole in the cork, to allow the circulation of air, and to admit the addition of fresh solution without disturbing the plant. This tube should be kept plugged with freshly burnt asbestos.

4. Take two well germinated **Pea** seeds, the plants being of about the same size, and place in bottles, one containing distilled water, and the other the solution prepared as above, and watch from day to day. Whilst the food material in the seed is still available both will grow well, but when this supply is exhausted the plant in the culture solution will soon begin to grow more rapidly than the one in distilled water.

5. To show the manner by which the food is taken in by the root-hairs, perform the experiment on **osmosis** described on p. 36.

6. Place a piece of smooth and polished marble in a dish, and cover over with a thin layer of clean sand or of sawdust. Moisten and sow some seeds of Mustard. Cover with a tile and keep moist and warm. When there is a good crop of Mustard, clean off the plants and the sand or sawdust. The surface of the marble will be grooved with lines where the roots of the Mustard have eaten their way. *Living roots give off acid sap which dissolves the materials of the soil.*

7. Take a **Turnip** or **Carrot** root, place in a hyacinth-glass so that it just touches the water contained within, and keep in a warm place. After a time the leaves will begin to sprout from the upper part of the root, and root fibres from below. They grow at the expense of the food material stored up in the swollen root, which gradually becomes shrivelled. *Swollen roots store up food material for the future use of the plant.*

CHAPTER IV.

THE STEM.

A.—Structure and Growth.

(Read pages 40–58.)

Material required :—Seeds for germination, Young Sunflower stems, Young Bean and Pea plants, Wheat or Oat plants, Branches of trees.

1. Germinate two sets of seeds in damp sawdust. Keep one set in the light, and the other in the dark. As they germinate, examine and compare. Note that the plants which have been germinated in the light have stems and leaves of a green colour, whilst those grown in the dark are pale in colour and look poor and sickly. *The substance (chlorophyll) which gives the green colour to plants is only formed under the influence of light.*

2. Take some **Sunflower** stems, about two or three months old, and examine. Note—

- *a.* The shape. Rounded at the lower part, and somewhat polygonal above (the shape is best seen by making a section with a knife).
- *b.* The surface rough, with short, stiff hairs.
- *c.* The colour of the stem (green).
- *d.* The arrangement into nodes and internodes (see p. 222).
- *e.* The consistency of the stem. It is not very woody. It dies down every year. (Such a stem is said to be **herbaceous.**)
- *f.* The arrangement of the leaves. They (at any rate, the lower ones) come off in pairs, the alternate pairs being at right angles to the pairs above and below them (**opposite** and **decussate** leaves).
- *g.* At the apex of the stem a **bud**, consisting of young leaves folded over one another. Sketch.

3. Cut across the stem with a sharp knife, and examine. Note—

- *a.* In the centre a greenish white soft portion. The **pith**, or **medulla.**
- *b.* Around this a ring of somewhat oval masses. The **fibro-vascular bundles.** (If the stem is quite fresh, drops of water may be seen issuing from these bundles.)
- *c.* Outside these bundles the **cortex.**
- *d.* On the exterior of the stem a very thin skin (the **epidermis**), (Figs. 63 and 69, *A*).

(The further structure of the parts of the stem is dealt with in the Chapter on Microscopic Work, p. 244.)

Sketch the section of the stem.

4. Take a piece of Sunflower stem six or seven centimetres long, taking care that there is at least one node in it. Boil in water for twenty minutes to half an hour, so as to thoroughly soften the pith and cortex. With a sharp penknife remove the epidermis and cortex. Note the fibro-vascular bundles that run like threads along the stem. With a needle carefully separate several, and note that they run parallel to one another. Note at the node that some of them bend out to pass into the leaves. Cut the stem longitudinally, and with a needle carefully clean away the pith. Note that in the internode there is, as a rule, no lateral fusion of the threads. At the node not only do some bend out, but some are fused. Note the strength of the bundles. Sketch.

5. Repeat the experiment with another piece of the stem, and soak it in an acid solution of **aniline chloride** or **sulphate** for five or ten minutes. Wash well and examine. The bundles will be stained yellow, whilst the other parts of the stem will be unstained (see p. 243). This will enable the course of the bundles to be traced more readily.

6. Repeat the experiments in paragraphs 2, 3, 4, and 5 on the stems of young **Bean** and **Pea** plant, and note the points of resemblance and of difference. Make sketches of all the work done.

The Sunflower, Bean, and Pea are examples of the Dicotyledonous plants where, in the young stem, the fibro-vascular bundles form a ring around the central pith.

7. Take a well-grown plant of **Wheat** or of **Oats**, or of some large **Grass**. Note—

a. The long green stem with several swellings at intervals along it (**nodes**).

b. At each node a single leaf given off, the lower part of which forms a sheath around the stem.

c. The consistency of the stem (**herbaceous**).

d. The shape of the stem (**rounded**).

e. The surface of the stem is smooth. (This can be best seen on removing the sheath of the leaf.)

Make a sketch showing these points.

8. Cut across the stem near its base, examine and note—

a. The interior is hollow, there is no central pith.

b. The fibro-vascular bundles are scattered irregularly through the soft tissue of the stem.

Make a sketch showing these points.

9. Cut across a node, examine and note—

a. The stem is solid right through.

b. The fibro-vascular bundles, instead of being arranged in a regular ring, are scattered through the whole stem.

10. Make a longitudinal section of the stem, including at least one node. Soak in solution of aniline chloride for a few moments, wash and examine. Note that the bundles run straight through the internode without fusion, but at the node the bundles run across the stem, forming a network. Sketch.

The Wheat or Grass is an example of a Monocotyledonous plant where the bundles are irregularly scattered through the stem.

(For further differences between the bundles of the two groups of plants, see the Chapter on Microscopic Work, p. 247.)

11. Take a branch of a tree, such as **Oak, Apple,** or **Plum,** which is two or three years old ; examine and note—

a. The consistency of the stem (**woody**). It has lasted for several years.

b. The colour, at any rate of the older part, is brown.

c. The stem is divided into nodes and internodes. The leaves come off singly at the nodes.

d. In the **axil** of each leaf (the angle the leaf makes with the stem) there is a small bud. Sketch.

12. Cut a transverse section of the branch with a sharp knife. Note—

a. The central soft **pith.**

b. Around this two or more rings of harder **wood.** The number of rings depends upon the age of the branch ; a fresh ring is formed each year outside that of the previous year, so that the oldest wood is towards the centre of the branch, and the number of rings tells the age of the branch.

c. On examining the wood with a lens numerous minute holes can be seen in it. These are the cut ends of the **vessels** which are present in the wood.

d. Outside the wood a darker ring, somewhat dotted. The **bast or inner bark.**

e. The **cortex,** which surrounds the bast.

f. The thin **epidermis** which surrounds the whole.

g. Faint lines radiating from the pith to the cortex, and passing through the wood and bast. The **medullary rays.**

Make a sketch of the cut branch.

13. Examine the section of the trunk of an **Oak,** or other convenient tree. Compare with the transverse section of the branch, and note the corresponding parts. Note—

a. The difference between the inner and the outer parts of the wood. The inner part (the **duramen,** or **heart wood**) is denser and harder than the outer (**alburnum,** or **sap wood**) ; the latter is much looser in its texture, the cut ends of the vessels being much more evident. (In many trees there is a difference in colour, the duramen being much darker than the alburnum.)

b. The very evident medullary rays radiating from the pith towards the bark.

c. Numerous cracks which can be seen also radiating from the centre. These cracks run along the line of the medullary rays ; they are caused by the shrinking of the wood as it dries, and have been formed along the lines of least resistance.

d. The bark on the exterior. This differs much in various trees. In some it is quite smooth, in others it is very rugged, owing to portions peeling off. Sketch.

B.—Functions.

Material required :—Flower head of Lily of Valley or Hyacinth, Growing plant of Geranium, Potato, Bulbs of Onion or Hyacinth, Corm of Crocus.

14. Place a flower head of a **Lily of the Valley**, white Hyacinth, or other white flower with its stalk in a solution of eosin (red ink will do very well). Note after a short time that there will be coloured lines in the white of the flower, showing that the liquid has been carried up to the flower by the stem.

15. Take a **Geranium** or other similar plant growing in a flower-pot. Keep it watered with a solution of eosin. After a few days a red colour will be visible in the veins of the leaves, showing that the solution has passed up to them. Cut the stem across near the base. Note that only the fibro-vascular bundles are stained. Make a longitudinal section of the stem. Trace upwards the stained bundles. The water absorbed by the root is carried up the stem by the fibro-vascular bundles.

16. Take a **Geranium**, or, better still, a more woody plant, growing in a flower-pot. With a sharp knife remove a ring of bark from the stem, taking care to cut right down to the wood, but not to injure it. Very soon a little drop of sap will appear from the upper part of the wound upon the cut surface of the inner bark. Cover over the wound with cotton wool to protect from evaporation : the upper part of the stem and the leaves will remain fresh, showing that the water is still passing up the stem. *The sap passes up by means of the wood, and is carried down by the inner bark.*

Stems as Storehouses of Food.

17. Examine a **Potato**. Note its general swollen shape, in this respect resembling the swollen root of the Turnip. The tough brown "skin" (cortical tissue). The numerous "eyes." These are buds. Cut out one or two of the eyes with a portion of the surrounding Potato, and plant them in soil in a flower-pot, keeping them in a warm place and covered over from the light. Keep the earth well watered. The eyes will grow to form Potato plants. Cut a Potato across, and treat the cut surface with tincture of iodine. It will be turned blue, showing the presence of starch (see p. 244). Take another Potato, and keep it in a warm damp place. Stems will grow out from several of the eyes, and the substance of the Potato will become shrivelled.

18. Examine an **Onion**. Note its general shape and appearance, from the under side the numerous fibrous roots, the exterior covered with brown scales. Sketch.

Cut it into two longitudinally. Note :—At the base a flattened

portion from which the roots are given off (Fig. 86). This is the stem. The thickened scales overlapping one another that grow up from the stem. These are leaves. In the centre a young bud which will form the new plant. Sometimes a small bud will be seen growing in the axil of one of the scale-like leaves. Sketch.

19. Place the bulb of an **Onion** or of a **Hyacinth** in a hyacinth-glass so that it just touches the water. Keep it in a dark warm place until it begins to germinate. Then bring into the light, and watch day by day. Note how the plant grows at the expense of the food material that had been stored up in the bulb.

20. Examine the corm of a **Crocus** or **Gladiolus**. Note its general shape and appearance. The buds at the upper surface. At the base the numerous roots (sometimes the roots are wanting, and there is only an annular scar showing where they have been). The brown scales surrounding the whole. Sketch.

21. Cut the corm into two longitudinally. Note the outer skin, the swollen mass of the corm (compare with the Potato), the attachment of the roots below, the bud or buds above. Sketch.

22. Repeat Experiment 19 with a **Crocus** corm, and note how the plant grows and the corm diminishes.

23. Examine any other **bulbs** and **corms** available. Compare with those already examined, and note the points of similarity and of difference.

In the tuber and corm the food is stored up in the swollen stem, and in the bulb in the swollen scale leaves.

CHAPTER V.

BUDS AND BRANCHING.

(Read pages 59–68.)

Material required :—Branches, with buds, of Horse Chestnut, Hazel, and any other convenient trees.

1. Take a branch of **Horse Chestnut** from which the leaves have fallen. Note—

   a. The position of the buds. One at the end of the branch (terminal bud). Others on the sides of the branch (lateral buds). These are opposite to one another.

   b. Beneath each of the buds a somewhat oval or horse-shoe shaped scar, showing the spot from which the leaves have fallen. The lateral buds were formed in the angle or axil of the leaf (axillary buds).

   c. The little dots in the scars, like nails in a horse-shoe. These mark the point where the fibro-vascular bundles enter the leaves. Sketch.

   d. Examine a single bud. Note the scales which cover it,

they are brown in colour; round their edges they secrete a thick resinous liquid which makes the surface of the bud sticky. Note the way the scales overlap (imbricate, Fig. 98). Sketch.

e. Remove these outer sticky scales. Note their general shape and appearance. The scales immediately below are greenish, and also sticky. Remove these, and note the inner scales, which are covered with fine white hairs. These are the rudimentary leaves.

f. Make a longitudinal section through a bud, and note—the points where the leaves are attached (nodes), and the spaces between (internodes). Sketch.

2. Take a branch of **Hazel** without leaves. Note—

a. The position of the buds. The axillary buds are alternate. The fourth bud is immediately above the first, the fifth above the second, and so on. As these buds grow in the axils of the leaves, they show the way the leaves were distributed on the branch. Draw a line from any bud towards the left, passing each bud above in succession; it will describe one turn of a spiral and pass two other buds (three in all, counting the first) before it reaches the one directly above the first. The arrangement of the leaves is described as $\frac{1}{3}$; the numerator of the fraction showing the number of turns of the spiral, and the denominator the number of leaves. Sketch.

b. The leaf scars below each bud. They are smaller than in the Horse Chestnut.

c. The scales, which are destitute of resinous secretion. They are in effect stipules, falling off as the buds open. Sketch.

d. Make a longitudinal section through the bud, and note the nodes and internodes. Sketch.

3. Make transverse sections through as many leaf buds as possible. Examine with a lens, and make out the vernation. Sketch each.

CHAPTER VI.

LEAVES.

A.—Structure.

(Read pages 69–84.)

Material required:—As many different kinds of leaves as possible.

1. Take a plant of **Sweet Violet** and examine the leaves. Note—The leaf is divided into three parts.

a. The petiole or stalk, varying in length, attaching the rest of the leaf to the stem.

b. The lamina or blade, a flattened green expansion, somewhat kidney shaped, and provided with numerous branching veins.

c. At the base of the petiole the stipules, two small, green, somewhat lanceolate or linear outgrowths. Sketch.

2. Take some branches of **Oak**, **Beech**, or **Lime** with some of the leaves very young, just unfolding from the bud, and others much older. Note that whilst the young leaves have stipules at their bases, those which are older have lost their stipules (Deciduous stipules). Sketch in both cases.

3. Take a branch of **Rose**. Examine the leaves. Note—

a. The stipules at the base. They grow up attached for a short distance to the petiole (Adnate stipules).

b. The petiole, growing up between the numerous leaflets.

c. The lamina, divided into several separate leaflets arranged in pairs on either side of the stalk with one odd leaflet at the end. Sketch.

This is an example of a compound imparipinnate leaf. It is a compound leaf, not several simple leaves on a stem, because—

(1) There is a leaflet at the end. We never find a leaf growing at the end of the stem. There is always a growing point so that the stem can be prolonged beyond the leaves.

(2) The leaf falls off as a whole; branches of the stem never thus fall off.

(3) The position of the stipules show that it is a single leaf, not a branch with several attached.

4. Compare leaves of the **Bramble** and **Ash**. In the latter case there are no stipules at the base of the compound leaves. Sketch.

5. Examine leaves of the **Strawberry** or of a **Clover**. Note—

a. The stipules at the base.

b. The petiole.

c. The lamina consisting of three leaflets radiating from one point at the top of the stalk. Sketch.

This is a compound leaf. (Why?) The leaflets being arranged in a palmate manner.

6. Examine as many leaves as possible, and write out their description as directed on page 185.

B.—Functions.

(Read pages 85-90.)

Material required:—Leafy plants in pots, *i.e.* Geranium, Leaves of Ficus Elastica, Cotyledon or other succulent plants, Plants of Elodea Canadense or other water plants, Growing plants of Tropæolum, Pea and Bean seeds.

1. *Transpiration.*—Take well-grown leafy plants, growing in small pots. Cover each pot with sheet indiarubber, fastening tightly round the stem. The object of this is to prevent loss of

water by evaporation from the pot or from the surface of the soil. Weigh both plants. Keep one in a bright warm situation, and the other in a cool place with dim light. Weigh again at intervals of an hour. Note the different loss of water by transpiration. The experiment should be continued for several hours.

2. To prove that transpiration takes place by means of the stomata. Take two similar leaves of **Ficus Elastica**. When the bleeding of the latex from the cut end has ceased, place a piece of rubber tubing over the end of the leaf stalk, bending over the free end of the tube, and fastening it tightly to the stalk, so as to prevent evaporation taking place from the cut ends. Weigh the leaves and suspend for two or three hours side by side. Weigh again, so as to obtain the ratio of loss from the two leaves. Rub vaseline carefully over the upper surface of one leaf and the under surface of the other. This blocks up the stomata, preventing so much loss. Leave suspended for a day and then weigh again; note that the leaf which has the upper surface smeared with vaseline loses much more in proportion than the one whose under surface is covered.

3. To show that the presence of "bloom" on many succulent leaves prevents a too rapid loss of water. (Bloom consists of a waxy formation on the leaves and other parts of plants.) Take two similar leaves of **cotyledon** or some other convenient succulent plant, taking care not to injure the bloom. Protect, as before, the cut end of the petiole from evaporation. Hang up, after weighing, for an hour or two in a dry place. Weigh again, so as to determine the normal rate of transpiration. Carefully sponge one leaf with water at the temperature of 35° C., so as to remove the bloom. When dry weigh both leaves again, and suspend for twenty-four hours in a warm place. Weigh, and note that the leaf from which the bloom has been removed has lost water at a greater rate than the one which is uninjured.

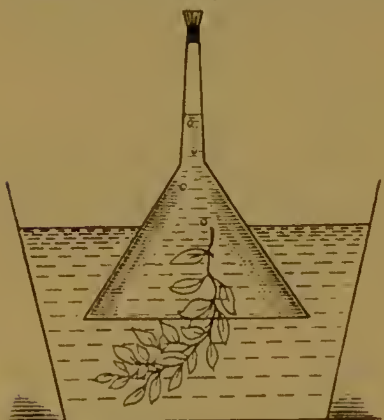

FIG. 341.—Apparatus to show the decomposition of carbon dioxide by green plants.

4. *Absorption of* CO_2 *Gas, and Elimination of Oxygen.*—Take a vessel of spring water; if this is not available, a little soda water added to the water in the vessel will supply the needed carbon dioxide. Arrange a funnel with its broad end downwards, so that it is entirely under the water. Cork the upper mouth of the funnel so that it is full of water, and raise it slightly in the vessel. Place under the funnel some water plant—fresh Elodea Canadense will do very well. Place the vessel in the sunlight. After a while bubbles of gas are seen to collect upon the plant and

gradually to rise into the tube of the funnel. When a sufficient quantity has collected, on the tube being uncorked, taking care to hold the funnel so that the water is at the same height outside and inside, if a piece of wood with a glowing spark is plunged into the gas, the spark will be rekindled. This is due to the oxygen produced by the decomposition of the carbon dioxide.

5. To show that the presence of light is necessary. Repeat the experiment, keeping the vessel in the dark. No bubbles of oxygen are produced.

6. *Assimilation of Carbon and Formation of Starch.*—Take a plant of **Tropæolum** which has been growing vigorously in the light. Remove one of the largest and healthiest leaves. Boil for about one minute in water, then place in pure methylated spirit at a temperature of 50°-60° C. till decolourised. Place the leaf for a short time in an alcoholic solution of iodine diluted with water to about the colour of table-beer. When coloured wash with water and examine. The depth of the tint will show the amount of starch formed.

7. To show the disappearance of the starch in the dark. Grow a **Tropæolum** for a day or two in the dark. Repeat the above experiment with one of the leaves. Note there is no blue colour, showing that there is an absence of starch.

8. To show that starch is only formed where the light falls. Take a plant of **Tropæolum** that has been for a few days in the dark. Paste pieces of black paper up on one of the leaves. Keep the plant for some time in a bright light. Test the leaf, as in experiment 6. There will be no blue where the leaf was covered with the paper.

9. Take a **Tropæolum** plant which has been for some time in the dark. Cover one of the largest leaves with a photographic negative. Test as above. There will be a complete print of the negative.

10. *Respiration.*—Germinating seeds are the best for showing plant respiration. Soak some **Bean** seeds in water for twenty-four hours. Place in a bottle so as to about quarter fill it. Close the jar tightly and keep in a warm, dark place for a day or two. Test the air in the bottle for CO_2 by plunging in a lighted taper and a vessel of lime water.

11. Free oxygen is not needed for respiration. Soak ten or a dozen **Peas** in water for twenty-four hours. Carefully remove the testas. Fill a long test-tube with mercury and invert it mouth downwards in a vessel of mercury. Pass the Peas into the tube so that they float upon the mercury. Keep in a warm place for a day or two. Gas will collect at the upper part of the tube. Pass in a strong solution of caustic potash. The gas will be absorbed, showing that it is carbon dioxide.

12. To show that heat is produced during respiration. Soak a number of **Bean** seeds in water and allow them to begin to germinate. Pack them loosely in a large glass funnel. Support the funnel in a beaker containing a strong solution of caustic potash.

Suspend a thermometer with its bulb amongst the germinating beans, and another outside the funnel with the bulb in damp sawdust. Cover the whole with a bell jar, and take observations of the temperatures from time to time. The thermometer placed in the seeds will show a slightly higher temperature than the one in the sawdust.

CHAPTER VII.

FLOWERS.

(Read pages 99-123.)

Material required :—Flowers of Geranium, Anemone, Marsh Marigold, Hazel, Willow, and as many other plants as possible.

1. Take a flower of **Geranium**. Any wild Geranium, such as Herb, Robert, will do, or, failing this, a flower of the so-called garden Geranium (Pelargonium). Note—

a. The circle of five green leaf-like pieces round the outside. This is the **calyx**, and the separate parts the **sepals**.

b. The circle of coloured portions; more delicate than the sepals. The **corolla** consisting of **petals**. Remove the sepals and petals, making sketches of them.

c. The circle of (usually) 10 threads within the corolla. The **andrœcium** consisting of **stamens**. In the Geranium there is a tendency for the stamens to be united together by their bases. Remove one stamen, and note.

(1) The **filament** or stalk; more or less thread-like.
(2) The swelling on the top of most of the stamens, the **anther**, consisting of two lobes.
(3) On opening a nearly ripe anther, the fine dust within, the **pollen**.

d. In the centre the **pistil**, consisting of five **carpels** united together, except that at the upper part there are five short threads. Examine and note.

(1) At the base of each carpel a swollen portion, the **ovary**.
(2) Above the ovaries five **styles** united together, forming a beak.
(3) At the summit five thread-like **stigmas**.
(4) Open one of the ovaries. Within a single **ovule**. Sketch the stamens and carpels.

The Geranium is an example of a perfect flower, because both stamens and carpels are present; of a complete flower, because all four whorls are present; of a regular flower, because the sepals are alike as also are the petals; of a symmetrical flower, because

each whorl consists of the same number of parts. (The ten stamens really consist of two whorls of five each.)

2. Examine an **Anemone** or **Marsh Marigold** as an example of a perfect incomplete flower. Note—

   a. There is only one whorl of floral envelopes. This is the **calyx.** (The green leaves just below in the Anemone are bracts.)

   b. The numerous **stamens.**

   c. The numerous **carpels** in the centre. Sketch.

3. Examine a branch of Hazel as an example of imperfect flowers. Note—

   a. The long, cylindrical, pendulous catkins. Note that they consist of a number of scales (bracts) arranged spirally along the central stalk. Sketch. Remove one of the scales. Note its shape; wedge-shaped (cuneate). On its inner surface note (using a lens) two smaller scales (bracteoles), and eight **stamens** (Fig. 312).

   b. The bud-like cones on the side ends of the branches; they are distinguished from the true leaf buds by the presence of red threads at the upper part (Fig. 162). Note that they have a number of overlapping bracts. Remove the outer ones; there are no flowers in their axils. Remove some of the inner bracts; they have small flowers in their axils, each with two bracteoles. Remove a flower with its bracteoles. Examine with a lens, and note. A hairy **ovary** with minute teeth at the upper part (remains of a **calyx**), two red **styles**, showing that the pistil consists of two syncarpous carpels. Open the ovary. It is two-celled, with a single **ovule** in each cell. Sketch.

The Hazel is **monœcious** because both male and female flowers are on the same plant.

4. Examine specimens of **Willow** or of **Dog's Mercury**, and compare with Hazel. In both of these cases the flowers are imperfect and **diœcious**, because the male and female flowers are on separate plants.

5. Write out full descriptions of as many flowers as can be obtained according to the directions given on page 185.

CHAPTER VIII.

FRUITS.

(Read pages 134-141.)

Material required:—Fruits of Lily, Iris, Rhododendron, Thornapple, Pea, Wallflower, Honesty, Shepherd's Purse, Poppy, Pimpernel, Cow Parsnip, Radish, Sycamore, Maple, Plum, Orange, Grape, Blackberry, Apple, Buttercup, Strawberry, Rose, Acorn.

DEHISCENT FRUITS.

1. Examine ripe fruits of **Lily** or **Iris**. Note that the fruit splits open, and that—

   a. It splits in a longitudinal manner.
   b. The split opens directly into the centre of each cell.
   c. That the septa between the cells remain attached to the walls of the fruit, whilst they separate from one another at the centre. **Loculicidal dehiscence** (Fig. 260, I.).

2. Examine fruits of **Rhododendron, Azalea,** or **St. John's Wort.** Note—

   a. The splitting is longitudinal.
   b. Each septum divides into two by a partition down its centre.
   c. The septa remain attached to the walls of the fruit so that the fruit breaks up into a number of closed portions corresponding to the number of the cells present. **Septicidal dehiscence** (Fig. 260, II.).

3. Examine fruits of **Thornapple, Morning Glory,** or **Convolvulus.** Note—

   a. The splitting is longitudinal.
   b. It takes place along the line that the septa are attached to the wall of the fruit.
   c. Whilst the septa become detached from the wall of the fruit, they remain attached to one another in the centre. **Septicidal dehiscence** (Figs. 260, III., and 261).

4. Take fruits of **Pea, Laburnum,** or **Vetch,** which are nearly ripe. Note their shape and general appearance. Place on a sheet of paper, keep in a warm dry place, and examine from time to time. After a time they will split along both margins, the two valves curling back and ejecting the seeds. **Legume,** or **pod.**

5. Take nearly ripe fruits of **Wallflower, Stock,** or **Mustard.** Note the general shape; the cleft stigmas at the end, showing that they consist of two united carpels. Leave as before in a warm dry place. Note that when they dehisce the two walls begin to separate at the base. Note the **Replum** within. **Siliqua** (Fig. 266).

6. Take nearly ripe fruits of **Honesty**. Note the general shape, and compare with Wallflower. It is shorter and broader. Leave as before to dry. Note the similar dehiscence to that seen in the Wallflower. The broad, semi-transparent replum. Note the attachment of the seeds. **Silicula** with **latisept** replum (Fig. 297, III.).

7. Examine fruit of **Shepherd's Purse**, and compare with that of Honesty. **Silicula** with **angustisept** replum (Fig. 297, II.).

8. Examine fruits of **Columbine**, **Marsh Marigold**, **Monkshood**, **Larkspur**, or **Hellebore** (**Christmas Rose**). Note the general resemblance to a legume. On ripening they split along one edge only. **Follicles** (Figs. 264, 265).

9. Examine the fruit of **Poppy**. Note—
   a. The swollen base. The **ovary**.
   b. The absence of style.
   c. The disc-like portion with scalloped edges on the top of the ovary. The **stigma** (Figs. 235, 259).

On ripening the little holes that appear at the base of the stigmatic surface. **Capsule** with **porous dehiscence.**

10. Examine the fruits of **Pimpernel**, **Plantain**, or **Henbane**. Note the general shape and appearance. As they ripen, the upper portion of the fruit lifts off like a lid. **Pyxis. Capsule** with a **circumscissile dehiscence** (Figs. 258, 262).

In each of these fruits the seeds are scattered as the fruit dehisces.

SCHIZOCARPS.

11. Examine fruit of the **Cow Parsnip**, or **Hogweed**. Note—
   a. Its general shape; orbicular and flattened.
   b. It splits into two halves (**mericarps**).
   c. On separating there is seen to be a stalk (**carpophore**), a prolongation of the flower stalk, which passes up between the two mericarps, and to which they are attached by means of two slight threads. Sketch.

Separate the two mericarps, and examine with a lens. Note—
   a. The two faces. The inner, or ventral, by which the mericarps are attached, flat or slightly concave; the outer, or dorsal, slightly convex, and provided with longitudinal ridges.
   b. The ridges, five in number on each mericarp. One running along each edge of the mericarp, and provided with a membranous wing; one central, and two intermediate, between the central and marginal ridges.
   c. Four club-shaped marks (**vittæ**), one between each pair of ridges, and two similar marks on the ventral surface. Sketch.

Cut a thin transverse section of the mericarp. Examine with a lens or the low power of a microscope. Note the prominent ridges and the vittæ, which are glands full of oil. Sketch.

This fruit is an example of a **cremocarp**. Other examples are to be found in Caraway, Fennel, Coriander, Carrot, and other plants of the order Umbelliferæ (Figs. 268, 303, II., 304, 305). They differ in their shape, the number and arrangement of the ridges, and the number of vittæ.

12. Examine fruit of **Radish, Bird's-foot,** or **French Honeysuckle.** Note—

a. The general shape, long.
b. Constricted at intervals between the seeds. Sketch.
c. The presence of a more or less complete dissepiment between the seeds.
d. When ripe they split across transversely, breaking the fruit up into several one-seeded portions. **Lomentum.**

13. Examine fruit of the **Sycamore.** Note—

a. At the base a swollen portion which evidently contains two seeds.
b. The thin membranous wings growing from the summit of the swollen portion. Sketch.
c. When ripe the fruit splits between the swollen parts into two one-seeded portions. **Samara.**

Compare the fruit of the Maple. Note, in some cases the samaras are one-seeded, and do not split.

14. Examine fruits of the **Geranium** and **Mallow.** Note how, when ripe, they split up into one-seeded portions. In the Geranium there are five such portions, in the Mallow ten or more. Sketch.

Fleshy Indehiscent Fruits.

15. Examine the fruit of **Plum, Cherry,** or **Apricot.** Make a longitudinal section. Note—

a. The outer skin. **Epicarp.**
b. The fleshy mass below the epicarp. **Mesocarp.**
c. The stone, or **putamen,** in the centre. **Endocarp.** Sketch.

Remove the stone and crack it. Note within the single seed.

This is an example of the **drupe,** or **stone fruit.**

16. Examine the fruit of the **Blackberry** or **Raspberry.** Note—

a. The numerous fleshy fruits forming the aggregate mass.
b. Make a longitudinal section. Note the conical elongation of the flower stalk (**torus,** or **receptacle**) between the fruits.
c. Remove one of the fleshy fruits and examine. Note that it is a drupe with outer skin, fleshy mesocarp, and stone (endocarp) surrounding the seed.

Sketch the entire fruit—the longitudinal section and the structure of the individual drupe.

This is an example of an **etærio** of **drupes.** Each small drupe being called a **drupelet** or **drupel** (Fig. 282, II.).

17. Examine fruit of **Grape, Gooseberry,** or **Currant.** Note the general shape. Make a longitudinal section. Note—

a. The outer skin. **Epicarp.**

b. The pulpy interior. **Mesocarp** and **Endocarp.**

c. The numerous seeds embedded in the pulp. Sketch.

These are examples of the **berry.**

18. Examine **Orange.** Make a transverse section. Note—

a. The outer skin. **Epicarp.**

b. The pulpy interior. This differs from the pulpy interior of the true berry in being divided by a number of partitions into several cells or cavities.

c. The numerous seeds placed in the inner angle of each cavity. **Axile placentation.** Sketch.

Such a multicellular berry is a **hesperidium.**

19. Examine an **Apple** or **Pear.** Note at the top the remains of the calyx in the form of scales. Make a longitudinal section and a transverse section of another specimen. Note—

a. The outer skin.

b. The fleshy interior of the fruit.

These are not equivalent with the epicarp and mesocarp of the drupe, but are formed from the enlargement of the thalamus, which in the flower forms a concave cup.

c. Within the fleshy thalamus the cartilaginous core. This is the true fruit containing the seeds. Sketch.

These are examples of the **pome,** which is a pseudocarp, or accessory fruit.

Dry Indehiscent Fruits.

20. Examine the fruit of **Buttercup.**

Note the numerous dry fruits upon the end of the flower stalk.

Remove one, and open with a sharp penknife. Note the single seed within. Sketch.

Such a one-seeded dry fruit is an **achene,** and the collection is spoken of as an **etærio** of **achenes.**

21. Examine the fruit of **Strawberry.** Note the green calyx below, and the fleshy structure of the fruit, with the numerous seed-like pips upon it.

Each of these is really an achene, and the fleshy mass is the enlarged **thalamus,** which is conical. Sketch.

The Strawberry fruit is a **pseudocarp,** and consists of an **etærio achenes** upon the enlarged fleshy thalamus.

22. Examine the fruit of **Rose** (Hip). Note—

a. The general shape and appearance.

b. The remains of calyx at the apex. Sketch.

Make a longitudinal section. Note—

a. The "Hip" is the enlarged hollow thalamus.

b. The numerous dry fruits; **achenes,** placed within the hollowed thalamus. Sketch.

c. Remove a single achene, and note its general shape: the surface covered with silky hairs. Sketch.

This is an example of a **cynarrhodum,** which is a pseudocarp

forming an etærio of achenes, contained within the enlarged thalamus.

23. Examine an **Acorn.** Note—

a. The cupule, or cup, which surrounds the base (compare with the cupule in the Hazel and Beech). It is formed from the bracts surrounding the pistillate flowers.

b. The single point within, with hard, dry walls. Sketch.

It is an example of a **nut or glans.**

CHAPTER IX.

MICROSCOPIC WORK.

For the use of a Microscope, and Mounting and Staining, a larger text-book on the Microscope must be consulted.

Division A.—General Structure of Cells and Tissues.

(Read pages 6-25.)

Material required:—Ripe Tomato, Date "stone," Pinewood (lucifer match), Cork, Potato (young and old), leaves of Elodea Canadensis, leaf of Onion or Hyacinth, young Sunflower stem, Fern rhizome.

1. Mount on a slide a little of the pulp of a **Tomato** (no water will be needed, as a rule). Examine first with low and then with high power. Note—

a. The shape of the cells, rounded or oval.

b. The very thin cell wall.

c. Lining this, the layer of more or less granular protoplasm.

d. The well-marked nucleus in the protoplasm, with, usually, a distinct nucleolus within it.

e. Numerous granules (**chromoplasts**) of an orange or red colour, placed in the protoplasm, and especially numerous round the nucleus.

f. The large vacuole of cell sap in the centre. Sketch.

2. Treat some Tomato pulp with solution of iodine, mount and examine, first with low and then with high power. Note—

a. That the protoplasm is stained brown, whilst the cell wall is unstained.

b. That the nucleus becomes more evident by being stained darker than the rest of the protoplasm.

c. There is no blue stain (absence of starch). Sketch.

3. Mount another portion of the **Tomato** pulp in Schultze's solution (Chlor-Zinc-Iodine). Examine and note that the cell walls are stained blue (presence of cellulose) and the contents as in No. 2. Sketch.

4. Take the "stone" of a **Date**. Scrape away the brown outer coat so as to expose the endosperm, which has a pearly appearance. Cut very thin sections parallel to the surface of the stone.

a. Mount one in glycerine. Note the thick cell walls, with here and there pits, and in some cases slightly granular protoplasm within. Sketch (see Fig. 27).

b. Soak one for a few moments in solution of iodine. Mount in a drop of the same solution. Note the cell walls slightly stained yellow; the protoplasm, where present, yellowish brown. Sketch.

c. Soak another in Schultze's solution. Mount in a drop of the same. Note the cell-walls stained blue or violet. Sketch.

d. Mount a fourth in a solution of aniline chloride. Note the cell walls unchanged. These tests show the presence of **cellulose**.

5. Take an ordinary wooden **match** (for Pine), cut transverse sections. Soak in alcohol to get rid of the air bubbles. Repeat the above four observations. Note. With iodine the walls are stained yellow. The same with Schultze's solution, there being no blue. With aniline chlorine the walls are stained yellow. Sketch. These tests show the presence of lignin.

6. Make a thin longitudinal section of the match. Mount in glycerine, and note the numerous cells with bordered pits. Compare with Fig. 34. Sketch.

7. Repeat the observations in Experiments 4 and 5 on thin sections of Cork. Note that with iodine and with Schultze's solution they are stained yellow; with aniline chloride no change.

Warm slightly another section of Cork in solution of caustic potash. Mount in a drop of water and examine. The walls are stained yellow. Sketch.

These tests show the presence of Suber.

8. Mount a young leaf of *Elodea Canadensis* in water. Examine with the low and high powers. Note—

a. The shape of the cells—more or less elongated and placed end to end.

b. The numerous small rounded green bodies (chloroplasts) placed in the cell. Sketch.

Gently warm the slide, and re-examine. In many cases the protoplasm can be seen to be rotating in the cell. Sketch.

9. Place some branches, with their leaves, of Elodea in alcohol for a short time. The alcohol will gradually become green, owing to the solution of the chlorophyll. Mount a leaf in water and examine under the microscope. The chloroplasts are still present, but they have lost their green colour.

10. Cut open a **Potato**, and scrape a little with a scalpel, and mount the scrapings in water. Examine with the high and low powers. Note—

a. The numerous oval starch granules. In most can be seen the hilum and concentric rings (Fig. 7). Sketch.

b. Run in a little solution of iodine. Note that the grains are stained violet-blue.

11. Cut a very thin section of the **Potato**. Mount in water and examine to see the starch grains *in situ*. Stain with iodine and examine.

12. Cut up a very young **Potato** into small pieces. Treat with solution of picric acid. Wash with diluted alcohol and harden in strong alcohol. Cut a thin section just below the rind and parallel to it. Soak in dilute solution of iodine and mount in glycerine.

Examine under low and high powers. Note—

a. The cell walls ; thin and usually polyhedral.

b. The starch grains stained violet-blue. They are not present in all the cells.

c. Small rounded grains, which are stained brown. These are the **leukoplasts**. In some cases they are close to the starch grains, which have been formed from them. In other cases they alone can be seen in the cell. Sketch.

13. Cut longitudinal sections of leaf of **Onion** or **Hyacinth**. Mount in water. Examine first under low, then high, power. Note. In many of the cells long needle-shaped crystals (raphides) (Fig. 13). Sketch.

14. Cut up an old **Potato** into pieces and harden in alcohol. Cut sections just below the rind and parallel to it. Mount in glycerine, to which a little solution of iodine has been added. Note the cubical crystalloids (Fig. 14). Sketch.

15. Cut a longitudinal section of the stem of a young **Sunflower**, taking care to cut through one of the fibro-vascular bundles. Mount in glycerine and examine, first with low and then with high power. Note—

a. The shape of the various cells.

b. The thickening of varions cells.

Pitted, spiral, and other forms will be seen. Sketch.

16. Cut a longitudinal section of a **Fern** rhizome, taking care to cut through one of the fibro-vascular bundles ; mount in glycerine and examine, first with the low and then with the high power. Note especially the scalariform cells and vessels.

Division B.—Special.

A. *Structure of Stem.*

(Read pages 41-53.)

Material required:—Young Sunflower stem ; Elm, Hazel, Oak, or other tree ; Maize stem ; Hyacinth, Lily, or other Monocotyledon stems.

1. Cut a thin transverse section of the stem of a young **Sunflower** Mount in glycerine. Examine with the low power. Note—

a. The **epidermis** on the exterior, a single layer of flattened cells, some of which are prolonged into hairs.

b. The **cortical tissue**, several layers of cells thick beneath the epidermis.

c. The **vascular bundles**, variable in number. They are wedge-shaped, with the apical point towards the centre of the stem. Each bundle is seen to consist of three parts.

α. The **phlöem**, towards the exterior, consisting chiefly of the cut ends of fibres showing very little cell cavity.

β. The **cambium**, which lies next to the phlöem. This generally appears to have less well-defined cells, owing to their being full of protoplasm. If the stem is very young, the cambium is only within the bundles, but if the stem is somewhat older the cambium is seen to be developed between the bundles (interfasicular cambium), forming a complete ring round the stem (Fig. 69).

γ. The **xylem**, at the inner part of the bundle; the vessels showing well from being much larger in section than the surrounding cells.

d. The centre of the stem is filled with large thin-walled cells, the **pith**. In many cases there will be a quantity of air, forming air-bubbles, the cells having lost their contents. If the section is soaked for a short time in alcohol before mounting it will usually get rid of this air.

e. Bands of thin-walled cells running between the bundles and uniting the central pith with the external cortical tissue. Draw.

2. Examine the thinnest of your sections with a high power of the microscope. Note—

In the xylem, the vessels are arranged in radial rows. Their walls are thick. The cells around them are of two different kinds, some appear to be polygonal in section, with thickened walls and little or no cell contents (wood fibres); others are thinner walled, and possess cell contents (xylem-parenchyma). Sketch.

3. Mount a section in Schultze's solution, and note carefully which cells are stained. Those which have cellulose walls are stained blue, those which are lignified or have corky walls are stained yellow or brown. Sketch.

4. Mount another section in solution of aniline chloride. Note which cells are stained yellow (lignified walls). Sketch.

5. Make a radial longitudinal section of a **Sunflower** stem, taking care to cut through a vascular bundle. Mount in glycerine, and examine first with a low and then with a high power. Note—

a. The epidermal cells are oblong; many of them grow out into hairs.

b. The cortical parenchyma has shorter cells, thin-walled, with, frequently, chlorophyll grains.

c. The phlöem contains several kinds of cells.

α. The bast fibres, long pointed cells with thick pitted walls.

β. The sieve-tubes, long, thin-walled tubes, with transverse or oblique septa (Fig. 36). Protoplasmic contents are present. (Sieve-tubes are best seen if the section is first soaked in a strong solution of eosin in either water or alcohol.)

γ. Bast parenchyma, thin-walled, parenchymatous cells with faint pitted markings.

d. The cambium, thin-walled cells with dense protoplasmic contents.

e. Xylem. This, again, consists of several forms of cells.

α. Vessels, the most prominent constituents, large in size, the walls marked with pits or spiral or annular markings. The pitted vessels are the largest, the spiral and annular vessels are nearest to the pith.

β. Wood fibres, long and pointed, with pitted walls.

γ. Wood parenchyma, thin-walled cells, especially round the vessels towards the inner part of the xylem.

f. Pith, thin-walled cells with slightly pitted walls. Sketch.

6. Mount longitudinal sections in Schultze's solution and in solution of aniline chloride, noting in each case which cells are stained. Sketch.

7. Cut thin transverse sections of a small branch of **Elm, Oak,** or other convenient tree. Soak in alcohol, mount in glycerine and examine, first with the low and then with the high power. Note—

a. The epidermis will only be present in a very young twig. When present it is a single layer of cells, some of which may grow out into hairs.

b. Cork, one or more layers of square cells. Absent in very young twigs, strongly developed in those which are older.

c. The annual rings of wood very evident. The oldest wood towards the centre. Note that the xylem formed in the autumn (towards the outside of the annual rings) has thicker walls to the cells and smaller cell cavities than that formed in the spring. Note the vessels, wood fibres, and wood parenchyma.

d. Cambium outside the last ring of xylem. Thin-walled cells. Sometimes nuclei can be seen with the high power.

e. Phlöem, outside the cambium. This consists of the same elements that were noted in the Sunflower.

f. Pith in the centre of the stem. The cells are rounded, with pitted walls. Starch granules are often present, especially in winter.

g. Medullary rays, joining the pith with the outer cortex, and breaking up the xylem and phlöem into wedge-shaped bundles. Primary rays pass the whole distance from the pith to the cortex, secondary rays only pass a part of the distance, and have been entirely formed by the cambium (Fig. 68). Sketch.

8. Mount sections in Schultze's solution and in solution of aniline chloride. Note the cells which are stained and compare with the corresponding sections of the Sunflower. Sketch.

9. Cut longitudinal radial sections of the stem, soak in alcohol and mount in glycerine. Examine with the low and high powers, and compare with the section of the sunflower stem. Treat other sections with Schultze's solution and with aniline chloride. Examine and sketch.

The above have been examples of the Dicotyledon stem.

10. Germinate some **Maize** seeds. When they are well grown, preserve the stems in alcohol so as to remove all the air.

Cut thin transverse sections and mount in glycerine. Examine with the low power of the microscope. Note—

a. On the exterior an epidermis, a single layer of cells arranged in a rather irregular manner.

b. Irregular groups of schlerenchyma. Thick-walled cells, lignified (yellow with aniline chloride). These give strength to the stem. They are not present in all monocotyledonous stems.

c. A mass of parenchymatous ground tissue filling up the stem, and not separated into pith and medullary rays.

d. Numerous vascular bundles scattered through the ground tissue. The largest bundles are towards the centre of the stem, those towards the exterior are smaller but more numerous (Fig. 67). Sketch.

11. To study the structure of the vascular bundle, soak the section in solution of aniline chloride, and examine one of the largest central bundles with the high power. Note—

a. Four large lignified vessels of the xylem arranged like a V, with the angle towards the centre of the stem. The two vessels forming the angle are the smallest, and are the first formed; the one nearest the centre of the stem has an annular thickening. Often (especially in old stems) it is surrounded partially by an intercellular space, or air cavity, and the rings become isolated. The next small vessel usually has a spiral thickening, whilst the two large ones are pitted.

b. Surrounding the intercellular space thin-walled xylem parenchyma, unstained by the aniline chloride.

c. Surrounding the two pitted vessels, and between them, lignified xylem fibres with pitted walls.

d. Between the two limbs of the V, the phlöem consisting of sieve-tubes and bast parenchyma (cambiform cells) separating them.

e. Surrounding the whole bundle a sheath of schlerenchyma.

f. Total absence of cambium, and therefore of secondary growth (Fig. 74). Sketch.

12. Make radial longitudinal sections, mount in glycerine, and examine, making out the various parts. Sketch.

This is an example of a monocotyledonous stem. Others, such as Hyacinth or Lily, may be compared with it.

B. *Structure of the Leaf.*

(Read pages 70-72.)

Material required :—Leaves of Sunflower, Holly, Hyacinth, and any other convenient plants.

1. Make a transverse section of the petiole of a **Sunflower** leaf, mount in glycerine and examine with low and high powers of the microscope, comparing with the section of the Sunflower stem. Note—

a. The difference in shape. The petiole is somewhat reniform, the hollowed surface being dorsal, whilst the rounded part is ventral.

b. Numerous stomata, and beneath each stoma an intercellular air chamber.

c. Vascular bundles, three large and several smaller ones. The xylem towards the upper and the phlöem towards the lower surface of the petiole. The smaller bundles contain no cambium. Sketch.

2. Make sections of the petioles of **Holly** and of other leaves, and compare with the Sunflower, noting especially the number of bundles present and their general arrangement. Sketch in each case.

3. Strip off the epidermis from the upper side of the **Sunflower** leaf, mount in water and examine. Note the epidermal cells destitute of chlorophyll, the numerous stomata, the guard or stomatal cells, with chlorophyll. Sketch. Repeat with the epidermis of the under surface, note that the stomata are more numerous.

4. Repeat with the epidermis of the **Holly**. Note that there are no stomata on the upper surface, but numerous stomata on the lower one.

5. Place a portion of **Sunflower** leaf between two pieces of pith, and make transverse sections. Mount in glycerine and examine. Note—

a. The epidermis covering the upper and lower surfaces. On the outside this is covered with a continuous

layer, the cuticle. Several of the cells are prolonged into hairs. Note the presence of the stomata, and the guard cells seen in section.

b. The mesophyll, filling up between the two layers of the epidermis. It is divided into two portions. On the upper part the cells are closely packed together, whilst on the lower side they are more loosely arranged with numerous air spaces (Fig. 105).

c. The section of the nerves varying in appearance according to the size of the nerve. The largest show the xylem and phlöem very much as in the petiole, the smaller often reduced to little more than a single thickened cell. Sketch.

6. Make sections of other leaves and compare with that of the Sunflower. Sketch all specimens.

C. *Structure of the Root.*

(Read pages 30–32.)

Material required :—Roots of young Pea and Bean ; also of older plants of Wallflower, Maize, Hyacinth.

1. Take the root of a young **Pea** or **Broad Bean,** which has been hardening for several days in alcohol, and cut transverse sections near the apex, clear with "Eau de Javelle" (hypochlorite of soda), wash with water and then with dilute acetic acid, mount in glycerine and examine. Note—

a. Central pith, thin-walled parenchymatous cells.

b. Radiating groups of primary xylem. The number varies ; it is usually four (tetrach bundle), it may be as many as six, whilst in the Pea it is often only three (triarch bundle). The earliest formed and smallest cells are towards the outer part of the root.

c. The primary phlöem, alternating with the xylem, forming the same number of bundles.

d. Between these two groups of tissues there is a series of bands of parenchyma.

e. Outside the central cylinder the pericycle, or pericambium, thin-walled cells one layer thick opposite the phlöem, but two or three layers opposite the xylem.

f. The endodermis, or bundle sheath, a single layer of cells immediately outside the pericycle. The cells of the endodermis can usually be recognised by the presence of a dark dot on their radial walls.

g. Cortex, a thick band of parenchymatous tissue (Fig. 50).

h. The epiblema, or piliferous layer, a single layer of cells, forming the outer limit of the root. Several of the cells may be seen to grow out into root hairs. Sketch.

2. If sections are made of much older roots there will be found to have been formed secondary xylem between the primary. This

has been produced by means of cambium tissue developed just within the phlöem. Sketch.

3. Make sections of root of **Wallflower**, compare with those of the Bean and Pea. Note—

a. There are only two bundles of the primary xylem (Diarch bundle).

b. There is no central pith, the xylem bundles forming a plate across the centre of the root. Sketch.

4. Make transverse sections of the roots of **Maize**, **Hyacinth**, or of other convenient Monocotyledons. Examine and compare with the Dicotyledon roots already examined. Note especially the large but variable number of xylem and phlöem bundles (Polyarch bundles). Sketch.

QUESTIONS FOR EXAMINATION.

[*Those followed by a date are questions which have been set at previous examinations held in connection with the Science and Art Department, South Kensington.*]

1. How can you distinguish a plant from an animal?
2. Into what two great sub-kingdoms may plants be divided?
3. Describe fully the seed of a Bean. (1875 and 1878.)
4. Compare the seed of the Oat with that of the Bean.
5. Explain the terms "albuminous" and "exalbuminous," and mention some albuminous seeds.
6. Describe the structure of a living parenchymatous plant-cell. What chemical elements enter into the composition (*a*) of the cell-wall, (*b*) of the protoplasm? (1887.)
7. What are the composition and properties of cellulose?
8. Enumerate and describe briefly the most important substances which are formed *within* the protoplasm of plant-cells.
9. Give an account of the general properties of chlorophyll, and of the conditions which are necessary to its formation.
10. What remarkable change do plants show when they are grown in the dark? (1876.)
11. Why does heaping earth round Celery cause the stalks to be white? (1877.)
12. What is the nature of starch? How is it formed, and what is its use? (1879.)
13. Explain the structure of a cell and the changes it undergoes in the growth of a plant. (1878.)
14. What conditions modify the shape of cells?
15. How are thickened cells produced?
16. In what respects does the wood of the stem of a Conifer (Fir Tree) differ from that of a dicotyledonous plant? Describe the development of "bordered pits."
17. What is meant by a vessel? How is it formed, and what is its use? (1878.)
18. How are the cells, say in the leaf of a plant, increased in number?
19. Give an account of "parenchyma." Explain how it is formed. (1875.)
20. Describe what happens in the germination of a Bean seed. (1878.)
21. What requisites are needed for germination?
22. Compare the germination of the following seeds:—Broad Bean, Acorn, Cress, Mustard, Pine, Date, and Wheat.
23. Compare the modes of germination of seeds of the Oak and of the Beech. In what important respects do they differ? (1884.)
24. Describe the way in which roots grow. (1877.)

25. The seeds of Mustard and Cress will germinate on flannel soaked with rain-water. Will they go on growing under these circumstances? and if not, why not? (1879.)

26. When any vegetable material is burned, what constituents go off as gas? What are left behind? (1877.)

27. What are the principal substances which form the food of plants? (1875.)

28. What part of the food of a plant is taken up by the roots? (1878.)

29. Explain how the food is absorbed by the roots.

30. Of what substances in the plant is nitrogen an essential ingredient? How does the plant obtain the nitrogen? (1876.)

31. Why do plants require nitrogen, and in what form do they take it in? (1880.)

32. Explain the "rotation of crops."

33. Explain why the root of a turnip first grows faster than the stem, and then stops while the stem grows rapidly. (1877.)

34. What are the chief differences between a root and a stem? (1876.)

35. Suppose a piece of the axis of some flowering plant were shown to you, what appearances would enable you to decide whether it was part of a root or of a stem? (1882.)

36. Compare the appearance of a monocotyledonous and dicotyledonous stem as seen in transverse section.

37. What is the cause of the ring-like markings seen in the cross-section of a tree-trunk? (1876 and 1881.)

38. Describe and explain as much of the texture of a deal plank as can be made out with the naked eye. (1879.)

39. Explain the difference in the growth of the bark of a tree and that of the wood. (1880.)

40. What is the structure and use of cambium?

41. State generally what is the composition of a vascular bundle. Describe the longitudinal course of the vascular bundles in the stem of any Dicotyledon. (1887.)

42. Describe a "runner," a "rhizome," an "offset," and give examples.

43. Give a full account of a Potato, and explain as much as you can of its structure. (1875.)

44. Explain why a Potato is considered to be a stem. (1878.)

45. Describe and explain the structure of an Onion. (1876 and 1880.)

46. Give a botanical description of the part, in each of the following plants, which is commonly used as food:—the Potato, the Onion, the Turnip, and the Carrot. (1887.)

47. What are the essential differences between a node and an internode? Illustrate your answer by examples. (1884.)

48. Describe a bud. To what structures do the outer coverings correspond? What is the origin and use of the resinous secretion with which they are often covered? (1877 and 1881.)

49. Why are some of our fruit-trees thorny in the wild state, but not when cultivated? (1879.)

50. Mention, with examples, the different members of the plant which may be modified into tendrils.

51. Explain precisely how a tendril acts. (1881.)

52. Explain the process of grafting. (1876.)

53. What is the structural difference between a prickle (as in the Rose), and a spine (as in the Blackthorn). (1881.)

54. What is a leaf? What is its use to the plant? (1877.)

55. Describe the general structure of a leaf.

56. What are stomata? Where are they found in the plant, and what is their use? (1880.)

57. What is the general plan of arrangement of leaves on a stem? Why is it the most advantageous to the plant? (1881.)

58. What components of the atmosphere are taken from it by plants, and for what purpose? (1881.)

59. What is the cause of the green colour of plants. What is its use? (1875.)

60. State why absence of light is injurious to plants. (1881.)

61. Plants are said to "starve in the absence of light." Explain this statement. (1883.)

62. Why will a plant grown in a dwelling-room be less vigorous than one grown in the open air? (1879.)

63. What is meant by respiration? Describe an experiment for showing that plants respire. (1878.)

64. What is meant by transpiration? Under what circumstances do plants transpire most? (1879.)

65. What are the conditions, external and structural, which regulate the amount of evaporation from leaves?

66. Explain the action of the leaves of carnivorous plants.

67. Give instances in which leaves are only imperfectly developed. What useful purposes may they serve in such cases? (1882.)

68. Excluding the leaves forming the flower, we have three kinds occupying different positions on the stem in the higher plants. Briefly describe these.

69. What are bracts? Give some of their modifications.

70. What is meant by definite and indefinite inflorescence? Give examples and draw diagrams to explain your answer. (1875.)

71. If an inflorescence appears at the end of a branch of a tree, what is the effect on the future growth of the branch? (1879.)

72. Tabulate the principal indefinite inflorescences.

73. What is meant by "mixed inflorescence"?

74. What is a flower? What structures compose it, and what are their use? (1877.)

75. Give the names and brief descriptions of the enveloping and essential organs of a flower. (1875.)

76. Some English plants have one, others have two, and even three kinds of flowers. Explain how this is possible. (1879.)

77. Explain the terms "polygamous," "diœcious," "gynandrous," "syngenesious," "hypogynous," "perigynous," "inferior," "epigynous."

78. Explain fully the various respects in which a petal differs from a leaf. (1880.)

79. How do you explain the fact that while the leaves of most plants are green their flowers are of some other colour? (1878.)

80. What is pollen? What is its use? (1875 and 1878.)

81. What is meant by an inferior ovary? Give examples. (1875.)

82. What is meant by placentation? Describe the various forms.

83. What is a placenta? Describe the placentation in the Cruciferæ, the Leguminosæ, and the Liliaceæ.

84. Explain the terms "monadelphous," "diadelphous," "adnate," "innate," "versatile," "introrse," "extrorse."

85. Mention plants whose flowers contain nectar. What is its use? (1877.)

86. Describe the general structure of an ovule.

87. Explain the terms "orthotropous," "anatropous," "raphe," "hilum," "micropyle."

88. Draw a diagram showing the arrangement of the parts of the flower of a leguminous plant as seen in transverse section. Point out in what respects it differs from the arrangement typical of flowers generally. (1883.)

89. Draw a diagram showing the arrangement of the different parts of the flower of any Crucifer. (1882.)

90. Explain what is meant by an irregular flower. What is the advantage to a plant of having such flowers? (1878 and 1881.)

91. What provisions are made for cross-fertilisation?

92. What is a fruit?

93. Explain the terms "syncarp," "pseudocarp," "drupe," "achene," "pome."

94. Classify the dehiscent fruits.

95. What is a berry? What is the advantage to a plant to have this kind of fruit? (1877.)

96. Explain the essential differences of structure in the fruits of the Strawberry and Blackberry. (1881.)

97. How do the fleshy parts of the Strawberry, Blackberry, Apple, and Plum originate? (1876.)

98. Describe as fully as you can the structure of an Apple, and explain the origin of the different parts. (1879.)

99. Explain the terms "epicarp," "mesocarp," "endocarp," "loculicidal," "septifragal," "circumscissile."

100. Describe the fruits of a Buttercup and of a Pink. In what respects do they agree and in what respects do they differ? (1883.)

101. Describe, with sketches, the structures seen in transverse sections of the fruit of an Apple and of an Orange respectively. Point out, as far as you can, the parts in each case of which the structural value is the same. (1884.)

102. In what points of structure does an ovule differ from a seed? (1880.)

103. What are "endosperm" and "perisperm"? Also give the structure of the arillus.

104. There are three distinct modes in which water moves in the plant. State what they are, and describe the experiments by which you would prove their existence. (1884.)

105. What is the channel by which the leaves of a plant make up for the loss of water by transpiration? Where does the water come from?

106. Why can a tree be transplanted more safely in the winter than in the summer? (1877.)

107. When a branch of a tree is cut off, why do the leaves of the branch fade, while those of the tree remain fresh? (1876 and 1880.)

108. What constituents of sunlight are most effective in producing the chemical changes on which the nutrition of plants depends?

109. What is a hybrid? (1876.)

110. What are the characters of the two groups of flowering plants?

111. Describe the typical structure of a stamen. State the peculiarities characteristic of those of a Crucifer, a Composite, a Labiate, and a Grass. (1880.)

112. In what important respects does the fruit of a cruciferous plant (such as Shepherd's Purse) differ from that of a leguminous plant (such as a Pea)? How can the differences be accounted for? (1880.)

113. Describe the general structure of the ovary and of the fruit in Rosaceæ and Leguminosæ.

114. Compare the natural orders Labiatæ and Scrophulariaceæ.

115. Give an account of the structure of the head of a Daisy. (1880.)

116. What is the difference between an annual and a perennial plant? (1875.)

117. Describe the peculiarities of form and structure which are characteristic of the root. (1888.)

118. Describe the structure of a grain of Wheat and its mode of germination. (1888.)

119. Describe and explain, with reference to examples, the peculiarities of the root of biennial plants. (1890.)

120. Mention instances, from the following natural orders, of flowers in which the number of stamens is (*a*) less than or (*b*) more than that of the petals, explaining in each case how the difference in numbers arises—Ranunculaceæ, Cruciferæ, Scrophulariaceæ, Labiatæ. (1890.)

121. Give an account of the development, structure, and function of a pollen grain. (1890.)

122. Describe, with examples, the principal forms of compound leaves. What is the difference between a simple and a compound leaf? (1890.)

123. Through what part of the trunk of a tree does the sap rise? Describe an experiment to prove the correctness of your answer. (1890.)

124. Describe and compare the fruits of the following plants:—Buttercup, Cabbage, Gooseberry, Orange. (1890.)

125. Describe the position, number, and arrangement of the stamens in the flowers of the Cruciferæ, Compositæ, and Primulaceæ. (1891.)

126. Describe the general structure, position, and placentation of the ovary in the Umbelliferæ, Leguminosæ, and Labiatæ. (1891.)

127. Describe and briefly explain the influence of light upon the direction of growth of stems and roots. (1891.)

128. Describe and compare the corollas of any three of the following plants, and mention the natural orders to which each plant belongs:—Larkspur (Delphinium), Monkshood (Aconitum), Sweet Pea (Lathyrus), Dead Nettle (Lamium), Snap Dragon (Antirrhinum). (1892.)

129. In what respects of structure and function do the vessels of the bast (sieve tubes) differ from those of the wood? (1892.)

130. Describe and compare the fruits of the Wallflower (Cheiranthus) and Pea (Pisum), and those of the Parsley (Petroselinum) and Dandelion (Taraxacum). To what natural orders do these plants respectively belong? (1892.)

131. Describe and compare the inflorescences of the Wallflower, Parsley, and Daisy. (1893.)

132. Describe and compare the flowers of the Narcissus and the Hyacinth. (1893.)

133. The trunk of an oak tree when in full leaf is sawn all round so deeply as to cut through the sapwood. State and explain the effect of this operation. (1893.)

134. What is a rhizome? In what features does it differ from a root? Describe the mode of annual growth in length of the rhizome of any plant. (1894.)

135. Describe the arrangement of the stamens in the flower of the Buttercup, the Dead Nettle, and the Sweet Pea. Refer these plants to their natural orders. (1894.)

136. Explain the terms Annual, Biennial, and Perennial as applied to herbaceous plants, and give examples. (1894.)

137. Describe the changes which are undergone by an ovule in consequence of fertilisation. (1895.)

138. Mention any three climbing plants which grow wild in this country, and explain in each case how the plant climbs. (1895.)

139. What part of the plant is it which we eat, in each of the following "vegetables" used in cooking?—Broad Bean, French Bean, Brussels Sprout, Onion, Carrot. (1895.)

140. Describe the pistil of the Dead Nettle (*Lamium*), the Primrose (*Primula*), and the Shepherd's Purse (*Capsella*). (1895.)

141. What are the differences between (*a*) a thorn, (*b*) a leaf-spine, and (*c*) a prickle? Give examples. (1896.)

142. In what parts of plants are fats (or oils) principally deposited? Mention three commonly cultivated plants from which oil is obtained. (1896.)

143. What is the effect of light upon the direction of growth of stems and leaves? (1896.)

144. Distinguish between Thalamifloral, Calycifloral, and Gamopetalous Dicotyledons, giving examples of each. (1898.)

145. Describe the appearance of a shoot which has grown out of a Potato in the dark, and account for its peculiarities. (1898.)

146. Distinguish between syncarpous and apocarpous fruits, and give examples of common table fruits under both heads. (1899.)

147. Explain clearly how starch is formed in a Potato and from what source it is derived. (1899.)

The Controller of His Majesty's Stationery Office has kindly given permission to use the following Papers.

EXAMINATION PAPER, 1901.

(EVENING.)

Elementary Stage.

You are not permitted to answer more than *six* questions.

You must attempt the *first* question on the paper. The remaining *five* you may select from any part of the paper for this stage.

1. Refer the specimen placed before you to its natural order, giving your reasons, and describe it, taking the parts (*when present*) in the following order:—

Stem,	Flower,	Pistil,	
Leaf,	Calyx,	Fruit,	
Inflorescence,	Corolla,	Seed.	
Bracts,	Stamens,		(25)

2. Explain clearly what is meant by transpiration. Describe an experiment which will enable you to demonstrate the existence of transpiration. (15)
3. In what characters do the Umbelliferæ (*a*) resemble, (*b*) differ from, the Compositæ? (15)
4. Many flowers possess petals which are brightly coloured and marked with lines or dots; what is the meaning of these characters? Give examples to illustrate your answer. (15)
5. Enumerate the chief characters wherein monocotyledons differ from dicotyledons. Give three examples of each of these groups of plants. (15)
6. Describe and explain as far as you can the principal changes to be observed during the germination of a bean or a pea. (15)
7. What is meant by the terms *drupe*, *bulb*, *tuber*, *phyllode*, *aril*? Give one example of each. (15)

8. In what ways do perennial plants protect the growing points of their stems during winter? Illustrate your answer by briefly describing three examples. (15)
9. Describe the principal kinds of tissue to be seen in the wood of a dicotyledonous stem, and state the special use of each to the plant. (15)
10. Describe the gynæcium (pistil) in any *two* of the following plants:—Snowdrop, Marsh-marigold (*Caltha*), Beech. (15)
11. What is a tendril, and what is its use to the plant? Give examples of three different kinds of tendrils. (15)

EXAMINATION PAPER, 1901.

(DAY.)

Elementary Stage.

You are permitted to answer only *six* questions.

You must attempt the *first* question on the paper. The remaining *five* you may select from any part of the paper for this stage.

1. Refer the specimen placed before you to its natural order, giving your reasons for doing so, and describe it fully, taking its organs (*when present*) in the following order:—

Stem,	Flower,	Pistil,
Leaves,	Calyx,	Fruit,
Inflorescence,	Corolla,	Seed.
Bracts,	Stamens,	

(25)

2. Describe carefully the stipules in any three examples you may select, and explain their uses to the plant in each case. (15)
3. What is meant by a perigynous flower? Illustrate your answer by a description of the flower of the pear or apple. (15)
4. What is meant by the terms *duramen*, *corm*, *follicle*, *aril*, *vernation?* Give one example in illustration of each. (15)
5. What are "sleep movements"? Illustrate your answer by two examples. (15)
6. Describe the structure of the phloem in the stem of any dicotyledon you may select, and explain the uses of the different parts of the phloem. (15)
7. Fully describe the seed of any albuminous seed, pointing out briefly how the different parts have been formed. (15)
8. Give two examples of each of the following, and state the essential differences between them:—annual, biennial, perennial. (15)
9. Give a short description of the root-system of a young dicotyledonous plant. Enumerate the more important functions discharged by roots, and explain how the roots are specially adapted to perform these functions. (15)
10. In what essential characters do the Scrophulariaceæ (*a*) resemble, (*b*) differ from, the Labiatæ? (15)
11. Describe the structure of the epidermis of a leaf, and state the uses of the various parts. (15)

EXAMINATION PAPER, 1902.

(EVENING.)

Elementary Stage.

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*1. Refer the specimen placed before you to its natural order, giving your reasons; describe it, taking the parts (*when present*) in the following order :—

Stem,	Flower,	Gynœcium,
Leaf,	Calyx,	Fruit,
Inflorescence,	Corolla,	Seed.
Bracts,	Andrœcium,	

(24)

2. Mention the different forms which may be assumed by the stipules of plants. Give one example of such, and state the special use of the stipules in each case. (14)
3. Describe the appearance of a seedling which has been grown in darkness, and compare it with one grown under ordinary conditions of daylight. (14)
4. Describe any arrangements which are adapted to secure cross-pollination in three different Ranunculaceous flowers. (14)
5. Explain why it is easier to split a piece of wood in the direction of the grain than across it. (14)
6. Compare carefully the flower and fruit of a Rose with those of a Buttercup, and explain, by means of diagrams, the principal differences between them. (16)
7. What is meant by a Medullary Ray? Where are medullary rays found, and what are their uses? (14)
8. Describe fully the bulb of *either* the White Lily (*Lilium candidum*) *or* the Onion. Explain how the scales are formed, and their use to the plant. (16)
9. What is a Placenta? Describe the placentæ of the Wallflower, Primrose, and Lily. (14)
10. Mention the chief characters by means of which a root can be distinguished from a stem. (16)
11. What is Endosperm? What is its use to the plant? (14)

EXAMINATION PAPER, 1902.

(DAY.)

Elementary Stage.

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You must attempt the *first* question on the paper. The remaining *five* you may select from any part of the paper for this stage.

†1. Refer the specimen placed before you to its natural order, giving your

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* The specimen provided was *Alyssum Saxatile* (N.O. Cruciferæ).

† The specimen provided was *Lotus Corniculatus* (N.O. Leguminosæ).

reasons; describe it, taking the parts (*when present*) in the following order:—

Stem,	Flower,	Gynæcium,
Leaves,	Calyx,	Fruit,
Inflorescence,	Corolla,	Seed.
Bracts,	Andrœcium,	

(24)

2. Describe fully the leaf of a grass, and explain in what respects it differs from such a leaf as that of the Apple or Pear. (15)
3. State fully how you would determine whether a plant belonged to the natural order Scrophulariaceæ or Solanaceæ. (15)
4. Describe the features seen in a cross-section of a piece of wood (*e.g.* of oak or ash) when examined with a lens. Illustrate your answer by means of a diagram. (15)
5. Describe any three fruits which are adapted for dispersal by wind, explaining the nature of the adaptation in each case. (15)
6. Describe the inflorescence of a Daisy and of a Dead-nettle, pointing out the features of (*a*) resemblance, (*b*) difference, existing between them. (15)
7. Write a short account of the chief modes of vegetative propagation occurring in wild plants. Illustrate each method by one example. (15)
8. Explain how you would investigate the rate of growth in length of a root, indicating the precautions you would observe in conducting your experiments. Illustrate your answer by a diagram. (16)
9. Describe the flower of the Rose, and explain why it is said to be perigynous. (15)
10. How are the leaves arrayed on the twigs of a Horse-chestnut (or a Sycamore)? Point out any special adaptations which bring about the full exposure of the leaves to the light. (15)
11. Describe fully the carpels of the Pea and of the Wallflower, and state the uses of the various parts. (15)

EXAMINATION PAPER, 1903.

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Elementary Stage.

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*1. Refer the specimen placed before you to its natural order, giving your reasons; describe it, taking the parts (*when present*) in the following order:—

Stem,	Flower,	Gynæcium,
Leaves,	Calyx,	Fruit,
Inflorescence,	Corolla,	Seed.
Bracts,	Andrœcium,	

(25)

2. What is a biennial plant? Mention three examples, and point out any special adaptations to a biennial habit that they may show. (12)

* The specimen provided was *Cytisus Laburnum*.

3. What is meant by the transpiration current? How would you demonstrate its existence, and ascertain its path in the plant? (15)
4. From what source does a green plant obtain the carbon it requires? How would you test your statement by an experiment? (15)
5. Describe the petals in a Buttercup, Christmas Rose (*Helleborus*), and Columbine (*Aquilegia*), and point out any features of (*a*) similarity, (*b*) difference, between them. (15)
6. What is a cladode? Give an example, and show how a cladode can be distinguished from a phyllode. (15)
7. Mention three flowers that possess syncarpous ovaries, and describe carefully the ovary in each case. (15)
8. Explain clearly the difference between a drupe and a berry, both as regards the fruit and the seed. Illustrate your answer by reference to one example of each. (12)
9. How would you distinguish between a thorn and a prickle? Mention two plants possessing prickles, and state what you consider to be their use to the plant. (12)
10. A certain regular flower is found to possess five sepals, five petals, five epigynous stamens, and an inferior syncarpous bilocular ovary, containing pendulous ovules. What is its natural order? Mention three plants belonging to this order. (12)
11. Describe fully any insectivorous plant with which you may be familiar, and explain the nature of the mechanism by which the insect is caught. (15)

EXAMINATION PAPER, 1903.

(Day.)

Elementary Stage.

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*1. Refer the specimen placed before you to its natural order, giving your reasons; describe it, taking the parts (*when present*) in the following order:—

Stem,	Flower,	Gynæcium,
Leaf,	Calyx,	Fruit,
Inflorescence,	Corolla,	Seed.
Bracts,	Andrœcium,	

(25)

2. Mention four thorny plants known to you. Explain how you would determine the morphological character of the thorns in each case. (15)
3. Compare the pistils of the Columbine (*Aquilegia*), Wall-flower, Rose, and Raspberry, pointing out the most important points of resemblance and difference between them. (15)
4. Describe the arrangements for ensuring cross-pollination in any two flowers belonging to the Compositæ that you may select. (15)
5. Describe two examples of each of the following:—
   Bulb, cladode, rhizome, tuber. (15)
6. Why is it that when some trees are cut down, "suckers" (or young

* The specimen supplied was *Cerastium tomentosum*.

shoots) often spring up at some distance from the old trunk? Describe any example of such a case that may be known to you. (15)

7. Explain as exactly as you can why it is well to thin out seedlings when sown thickly. (13)
8. In what various ways are leaves useful to a plant? Describe, with diagrams, a few examples of the arrangement of leaves on stems. (15)
9. What is a Cymose Inflorescence? Shortly describe and compare the inflorescences of a Buttercup, Forget-me-not, and Stitchwort (*Stellaria*). (15)
10. Describe fully a grain of Oat or Barley. Trace the changes you can observe when the grain is allowed to germinate. (15)
11. Describe carefully the root system of such a plant as a bean. Why do the roots take up the positions they are observed to occupy? (15)

EXAMINATION PAPER, 1904.

(EVENING.)

First Stage.

You are not permitted to answer more than *six* questions.

You must attempt the *first* question on the paper. The remaining *five* you may select from any part of the paper for this stage.

1. Refer the specimen placed before you to its natural order, giving your reasons; describe it, taking the parts (*when present*) in the following order:—

Stem,	Flower,	Gynœcium,	
Leaves,	Calyx,	Fruit,	
Inflorescence,	Corolla,	Seed.	
Bracts,	Andrœcium,		(25)

2. What is meant by photosynthesis? What experiments would you make in order to find out the nature of the processes you mention? (15)
3. Mention two plants each of which possesses a persistent calyx. Fully describe the calyx, and explain its use to the plant in both cases. (15)
4. Describe fully the leaf of any grass, such as wheat or rye grass. Explain the use of the different parts. (15)
5. Explain how it is that dandelions and plantains are able to live so successfully as weeds in a lawn. (15)
6. Describe the process of pollination in any *two* of the following:— Larkspur, Willowherb (*Epilobium*), Dead Nettle, Willow. (15)
7. Mention three plants that exhibit some special adaptation for the dispersal of the seeds. Describe fully the nature of the adaptation in each case. (15)
8. Contrast the mode of storage of reserve food in a Crocus, a Lily, and a Dahlia. (15)
9. How would you measure the rate of growth of a root? Point out any peculiarities in their mode of growth that distinguish roots from stems. (15)
10. What are the "veins" of a leaf? What are their uses? How would you show, by experiment, the correctness of your statements? (15)
11. Describe two examples of climbing plants. What are (1) the advantages, (2) the disadvantages, of a climbing habit? (15)

EXAMINATION PAPER, 1904.

(Day.)

First Stage.

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1. Refer the specimen placed before you to its natural order, giving your reasons; describe it, taking the parts (*when present*) in the following order:—

Stem,	Flower,	Gynæcium,	
Leaves,	Calyx,	Fruit,	
Inflorescence,	Corolla,	Seed.	
Bracts,	Andrœcium,		(25)

2. Give examples, with illustrative sketches, to show how plants arrange their leaves with reference to the source of light. (15)
3. Describe three examples of compound leaves. How would you distinguish such a compound leaf as that of the Vetch or Rose from a twig bearing simple leaves? (15)
4. Describe one example of each of the following:—Drupe, Capsule, Achene, Berry, and point out any features of resemblance and difference between them. (15)
5. How would you proceed to arrange an experiment to enable you to study the process of germination of a seed? Mention the chief precautions you would take in order that the seed should germinate satisfactorily. (15)
6. What is meant by irritability in plants? Explain this with special reference to climbing plants. (15)
7. What is meant by each of the following terms:—Dichasium, Corm, Seed, Pappus, Saprophyte? Give one example of each. (15)
8. Describe any special arrangements for preventing self-pollination in any *two* of the following:—Sweet Pea, Kidney Bean (*Phaseolus*), Willow, Sage (*Salvia*), Plantain. (15)
9. In what ways do umbelliferæ and compositæ (1) resemble, (2) differ from each other? Illustrate your answer by sketches. (15)
10. Mention three plants that possess stipules. Describe the stipules and draw them. Point out the special use of the stipule to the plant in each example you describe. (15)
11. Explain fully why it is that plants when they have been transplanted often droop in the daytime, and recover during the night. (15)

EXAMINATION PAPER, 1905.

(Evening.)

First Stage.

You are not permitted to answer more than *six* questions.

You must attempt the *first* question on the paper. The remaining *five* you may select from any part of the paper for this stage.

1. Refer the specimen placed before you to its natural order, giving your

reasons; describe it, taking the parts (*when present*) in the following order:—

Stem,	Flower,	Gynæcium,
Leaves,	Calyx,	Fruit,
Inflorescence,	Corolla,	Seed.
Bracts,	Andrœcium,	(25)

2. Describe a lenticel as fully as you can, and explain its use to the plant. (15)
3. Describe and explain as far as you can, what happens when a narrow ring, including all the tissues external to the wood, is cut from the trunk of a tree. (15)
4. Give three examples of *irritable* motile structures in plants, and explain how the movement may be advantageous to the plant in each case. (15)
5. Describe carefully the structure of a seed of any cruciferous plant, and indicate the use of the different parts. (15)
6. Describe and, as far as you can, explain the chief characters in which land plants differ from most water plants. (15)
7. What is meant by the grain of timber? On what structural differences does this appearance depend? (15)
8. Compare the carpels of the Pea, Willow, and Dandelion together, pointing out the chief features in which they (*a*) resemble, (*b*) differ from each other. (15)
9. Describe the structure of the winter bud of any tree you may choose, explaining the uses of the different parts. (15)
10. Describe exactly how you would arrange to grow some beans in order to watch all the stages of germination. Illustrate your answer by diagrams. (15)
11. Point out, in any two biennials you can describe, any special adaptations to the biennial habit which they show. (15)

EXAMINATION PAPER. 1905.

(DAY.)

First Stage.

You are not permitted to answer more than *six* questions.

You must attempt the *first* question on the paper. The remaining *five* you may select from any part of the paper for this stage.

1. Refer the specimen placed before you to its natural order, giving your reasons; describe it, taking the parts (*when present*) in the following order:—

Stem,	Flower,	Gynæcium,
Leaf,	Calyx,	Fruit,
Inflorescence,	Corolla,	Seed.
Bracts,	Andrœcium,	(25)

2. Describe the vegetative bud of any tree you may select, and state fully what happens when such a bud expands in spring. (15)
3. What are the "veins" of a leaf? Explain their principal uses to the plant. (15)
4. Bees are often seen visiting flowers. Explain why they do so, and

what is the exact use to the plant of such visits. Explain this with regard to any particular flower you may choose. (15)

5. Explain why it is that "cuttings" often succeed better when placed just inside the margin or circumference of a pot than when inserted at the centre. (15)
6. Describe three structures in different plants that are adapted to the storage of reserves of food. Give one example of each. (15)
7. Mention four plants belonging to the Scrophulariaceæ, and state in what sort of places each one grows, and when you might expect to find it in flower. (15)
8. How would you distinguish between a rhizome and a root? Describe two examples of rhizomes. (15)
9. What is the use of cork to a plant? State, with examples, in what parts of the plant cork is to be found. (15)
10. Describe, as fully as you can, what happens when a seedling bean is placed on its side, and is allowed to go on growing. (15)
11. Compare and contrast the fruits of the Rose, Strawberry, Blackberry, and Plum. (15)

EXAMINATION PAPER, 1906.

(Evening.)

First Stage.

You are not permitted to answer more than *six* questions.

You must attempt the *first* question on the paper. The remaining *five* you may select from any part of the paper for this stage.

1. Refer the specimen placed before you to its natural order, giving your reasons; and describe it, taking its organs (*when present*) in the following order:—

Stem,	Flower,	Gynæcium,	
Leaves,	Calyx,	Fruit,	
Inflorescence,	Corolla,	Seed.	
Bracts,	Andrœcium,		(25)

2. Describe carefully the arrangements of the flowers and fruits of *either* the Wallflower, *or* the Wild Mustard. Explain as fully as you can the use to the plant of the arrangement in the example you select. (15)
3. What is meant by transpiration? What is the use of the process to the plant? How would you ascertain the rate of transpiration in any given instance? (15)
4. Mention plants that possess stipules. Explain in each case the exact use of the stipules to the plant that bears them. (15)
5. Give an example of (1) a plant that climbs by means of leaf-structure, (2) a plant that climbs by means of stem-structure. Carefully describe the process of climbing in the case of one of them. (15)
6. What do you understand by phyllotaxis? Illustrate your answer by four examples which you have specially studied. (15)
7. To what structures is the green colour of a plant due? Explain what happens to them when you allow a green leaf to soak for some time in alcohol. (15)

8. Describe three fruits that are adapted for dispersal by animals, and explain the nature of the adaptation in each case. (15)
9. What is meant by the vernation and the venation of a leaf? Illustrate your answer by a description of two examples. (15)
10. In what way do Monocotyledons differ from Dicotyledons? Give three examples of each group. (15)
11. Explain the effect of pruning a shrub or tree, taking any definite example you may select as an illustration. (15)

EXAMINATION PAPER, 1906.

(DAY.)

First Stage.

You are not permitted to answer more than *six* questions.

You must attempt the *first* question on the paper. The remaining *five* you may select from any part of the paper for this stage.

1. Refer the specimen placed before you to its natural order, giving your reasons; describe it, taking its organs (*when present*) in the following order:—

Stem,	Flower,	Gynæcium,
Leaf,	Calyx,	Fruit,
Inflorescence,	Corolla,	Seed.
Bracts,	Andrœcium,	

(25)

2. Mention two plants that possess bulbs. Describe and explain carefully the structure of the bulb of one of them. (15)
3. Give some account of the modes of climbing to be met with in British climbing plants. (15)
4. What are "sleep-movements"? Describe fully these movements in any example you may have studied. (15)
5. Describe, and as far as you can explain, the appearance of a seedling that has been grown in continuous darkness. (15)
6. Write a short account of seed-distribution in *either* the Compositæ *or* the Rosaceæ. (15)
7. What is meant by the terms symbiosis, saprophyte, parasite? Mention and *briefly* describe *one* example of each. (15)
8. Explain what is meant by the torus. Compare the torus in the Ranunculaceæ and the Umbelliferæ. (15)
9. Describe, and state the functions of, the cotyledons in any *three* of the following plants:—Pea, Buckwheat, Castor Oil plant, Mustard. (15)
10. Describe a twig of *either* Hawthorn *or* Furze (*Ulex*), and explain the morphological nature of the thorns in the example you select. (15)
11. How is the plant enabled to take in the gases present in the atmosphere? Which of these gases are useful to the plant, and what is the nature of the use in each case? (15)

EXAMINATION PAPER, 1907.

(Day.)

Elementary Stage.

1. Describe the specimen placed before you. Sketch it, and name the parts. (You are expected to dissect it sufficiently to enable you to identify and describe its principal features.) (25)
2. What are the "veins" of a leaf? What are their uses? How would you experimentally test your statements? (15)
3. Mention three examples of plants with creeping stems, and explain the mode of arrangement of the leaves in each case. Illustrate your answer by sketches. (15)
4. Describe and compare the gynæcium of the Buttercup and Pea. (15)
5. Explain exactly what is meant by endosperm and perisperm. How are they respectively formed? (15)
6. What are lenticels? How would you ascertain the nature of the functions they discharge? (15)
7. Give two examples of irritability as shown by plants. Describe carefully what may be observed when the irritable organ is stimulated. (15)
8. Write a short account, illustrating your answer by sketches, of the mode of scattering the seeds to be seen in any four *capsular* fruits you may choose. (15)
9. Show, by means of a sketch, the way in which the roots of a seedling plant are arranged. Explain, as far as you can, the reason for the arrangement you describe. (15)
10. Give a short account of the mode of pollination as seen in any two flowers you may select. (15)
11. In what ways do the Solanaceæ (1) resemble, (2) differ from the Scrophulariaceæ? (15)

EXAMINATION PAPER, 1907.

(Evening.)

Elementary Stage.

1. Describe the specimen placed before you. Sketch it, and name the parts. (You are expected to dissect it sufficiently to enable you to identify and describe its principal features.) (25)
2. What is meant by sympodial branching? Explain your answer by means of diagrams, and describe one example of a sympodium that you may have studied. (15)
3. What functions other than the absorption of water do roots perform? Illustrate your answer by descriptions of any examples you may select. (15)
4. Describe fully what structures you would expect to find in a cross-section of a 3-year old branch of such a tree as a Willow. Illustrate your answer by sketches. (15)

5. What is the use of starch to a plant? Where is it found, and what structure does it show? (15)
6. Describe and explain as far as you can the appearance of a Potato that has sprouted (1) in a dark cellar, (2) on the surface of the soil. (15)
7. What are the principal modes in which seeds are dispersed? Describe the mode of dispersal in Gorse (*Ulex*), Violet, Willow, Blackberry. (15)
8. Describe the structure of a bulb, *e.g.* that of a Daffodil, and explain how such a bulb is formed. (15)
9. Many plants when wounded allow a milky juice to exude. What is this juice, and what do you know of its occurrence in plants? (15)
10. What is meant by a biennial? How does it differ from (*a*) an annual, (*b*) a perennial? Give two examples of each of these three classes of plants. (15)
11. In what respects does a flower of the Dead-nettle (*a*) resemble, (*b*) differ from, that of a Borage or a Forget-me-not? (15)

EXAMINATION PAPER, 1908.

(Day.)

Elementary Stage.

1. Describe the specimen placed before you. Sketch it, and name its parts. (You are expected to dissect it sufficiently to enable you to identify its principal features.) (25)
2. Describe three examples of thorny or spiny plants, and state what morphological structures the thorns represent, and the reasons which lead you to your conclusions. (15)
3. What are the functions that are discharged by a green leaf? Mention any structural characters that you think are associated with these functions. (15)
4. Describe, as fully as you are able, the structure of a leaf-bud, and explain what happens when the bud unfolds and develops into an ordinary leafy shoot. (15)
5. Describe the hairs on any *three* of the following plants: Nettle, Chickweed, Sea-buckthorn (*Eleagnus*), Drosera, Wallflower, Sunflower. (15)
6. Describe the process of germination in any albuminous seed which you may have studied. (15)
7. Describe the nectaries in any two flowers you choose, and explain how they are of use to the plant. (15)
8. What is meant by an evergreen plant? What do you think are the advantages and disadvantages connected with an evergreen habit? (15)
9. Explain the meaning of the following terms, and give one example of each :—Phyllode, Corm, Rhizome, Perisperm, Raphides (15)
10. In what respects does a herbaceous stem (*a*) resemble, (*b*) differ from, a woody one? Give two examples of each. (15)
11. Mention three common weeds that are known to you, and state in what sort of localities you would expect to find them growing. Describe briefly the fruits borne by each one of them. (15)

EXAMINATION PAPER, 1908.

(Evening.)

Elementary Stage.

1. Describe the specimen placed before you, sketch it, and name the various parts. (You are expected to dissect it sufficiently to enable you to identify and clearly describe the principal structures.) (25)
2. What general properties are characteristic of the Ranunculaceæ and of the Cruciferæ respectively? Illustrate your answer by reference to examples. (15)
3. What is meant by turgescence? What external conditions may affect it in the case of a plant growing in a pot? (15)
4. Explain what is meant by the torus. Contrast the torus of a Rose, Blackberry and Strawberry. (15)
5. Describe the structure, so far as you can, of a lenticel. Where are these structures to be found, and what are their uses? (15)
6. Describe the mechanism, in any three plants you may select, that is connected with the dispersal of the seed by the agency of wind. (15)
7. What is meant by the terms:—Phyllode, Corm, Radicle, Rhizome, Stoma? Give an illustrative example of each. (15)
8. What members of the Salicineæ are found growing wild in Britain? Describe the flowers of any one of them. (15)
9. Explain why it is that plants thrive better if grown in soil that has been deeply dug than in ground that has been badly cultivated. (15)
10. Compare the mode of germination of a Pea or Bean with that of a grain of Wheat. (15)
11. Describe, and sketch carefully, the structure of any vegetable cell that you may have examined. (15)
12. Describe fully the external characters of any branched leaf, and state how you would distinguish between the leaflets and leaves. (15)

INDEX AND GLOSSARY

THE END.

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